PUBLIC HEALTH DECISION-MAKING: THE VALUE OF GEOGRAPHICAL INFORMATION SYSTEMS (GIS) MAPPING

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"This tradition of mapping small areas to examine pockets of ill health and deprivation did not become well established in the NHS until relatively recently but is still a methodology capable of acting as a galvanising force for change in priority setting and policy-making at local level" (Donaldson, 1999)

ABSTRACT

Technologies such as geographical information systems (GIS) have emerged during the past two decades as part of the Information Revolution and include functions such as data storage, management, integration, analysis and presentation. GIS have wide and diverse applications in disciplines such as engineering, business/marketing, urban planning and environmental management but remain underused in public health. The thesis reports the findings of a mixed methods study examining the views and perceptions of public health practitioners on the value of GIS mapping in decision-making.

A case study design was chosen; the case issue (childhood lead [Pb] exposure) represents an example of the "case" which is defined as 'decision-making in public health'. The exploratory phase of the study combined heterogeneous data to produce a visualisation of lead contamination in Newcastle. The value of GIS in public health was explored in an interview phase. Twenty-two semi-structured interviews were conducted with decision-makers involved either directly or indirectly in public health practice. Interview recordings were transcribed and coded thematically for analysis.

Decision-makers tended to be positive about the use of GIS in public health and many volunteered potential opportunities to apply GIS mapping techniques further. Four discourses were highlighted through analyses, namely: data origins (Ontological Discourse), status (Power Discourse), application (Functionality Discourse) and reciprocity (Collaboration Discourse). The power of maps to integrate multiple, disparate datasets was found to be important and respondents felt, overall, that GIS mapping was a democratic means of communication.

Complexity frameworks are drawn upon to make sense of the research findings and to illuminate the need for non-reductionist models of decision-making in the public health context. The lessons learnt through this study can be translated to other fields, thereby sharing skills, knowledge and experience to promote collaboration and integrated thinking across the public health landscape.

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Abbreviations

ALPHA	Access to Learning for the Public Health Agenda
CDC	Centers for Disease Control and Prevention
CLEA	Contaminated Land Exposure Assessment
DEFRA	Department of Environment, Fisheries and Rural Affairs
DH	Department of Health
EBP	Evidence-based Practice
ESRI	Environmental Systems Research Institute
GIS	Geographical Information Systems
GONE	Government Office North East
HDA	Health Development Agency
HPA	Health Protection Agency
IMD	Index of Multiple Deprivation
IPPC	Integrated Pollution Prevention Control
LA	Local Authority
LREC	Local Research Ethics Committee
LSP	Local Strategic Partnership
MPH	Master of Public Health
MeSH	Medical Subject Headings
MOH	Ministry of Health (in relation to historical data)
NERIP	North East Regional Information Partnership
NICE	National Institute for Health and Clinical Excellence
NLM	National Library of Medicine
NSF	National Service Framework
ODPM	Office of the Deputy Prime Minister
ONS	Office for National Statistics
OS	Ordnance Survey
PCO	Primary Care Organisation
PCT	Primary Care Trust
PHO	Public Health Observatory
RCT	Randomised Controlled Trial
RMSO	Regional Maternity Survey Office
SARS	Sever Acute Respiratory Syndrome
SAT	Standard Attainment Test
SHA	Strategic Health Authority
SOA	Super Output Area
SPSS	Statistical Package for the Social Sciences
USA	United States of America
WHO	World Health Organisation

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Declaration

I declare that the work contained in this thesis has not been submitted for any other award and that it is all my own work.

Name:

Signature:

Date:

"The humble map is no longer confined to depicting dots on the physical landscape and can instead address embodied subjects to aid our understanding of situated health experiences"
(Mackian *et al.*, 2003, p.221).

Chapter 1: Introduction

1.1 Introduction

The introductory chapter to the thesis establishes the study context and provides an overview of the central concepts, themes and theories drawn upon within the study. The research questions are presented and the study methods are briefly described along with justification for the use of the case study approach. Discussion then moves on to how the work fits into the conceptual space of complexity and concludes with a description of the case example embedded in the study and an outline of the structure of the thesis.

The use of mapping in decision pathways is at the crux of this thesis. This is explored both first hand in a GIS mapping exercise and then through semi-structured interviews with public health professionals regarding their thoughts, beliefs and experiences of the use of GIS technologies and maps as evidence in decision-making pathways. The mapping exercise makes use of the traditional epidemiological paradigm to integrate multiple, disparate datasets relating to environmental lead contamination. GIS provides the bridge between the mapping phase and the qualitative interviews. The spatial exploration of environmental, demographic, socio-economic and historic datasets is a novel way of examining a contemporary public health issue. The power of GIS to combine and share data at the intellectual level parallels the underlying ethos of interagency working in the New Public Health. Childhood lead exposure represents the case example in the study.

1.2 The study context: public health

Public health is a complex and diverse phenomenon influenced by a panoply of contingent social, economic, political, environmental and cultural factors (MacKian *et al.*, 2003; Speller, Learmonth and Harrison, 1997). Accordingly, definitions of public health are varied and dynamic. Rather than concentrating on reductionist and mechanistic visualisations of health as the provision and administration of health services (Beaglehole *et al.*, 2004) practitioners call for the re-packaging of modern public health with the emphasis on 'health' instead of 'health care' (Hunter, 2003a).

Since the thesis is grounded in the public health context a clear definition of exactly what public health is and means in the 21st Century is necessary to

provide direction and boundaries[1] for the thesis. As far back as 1920, Winslow proposed the following definition of public health, which remains current today and has been drawn upon by (among others) Acheson in the 1998 Inquiry into Health Inequalities:

> *Public health is the science and art of preventing disease, prolonging life and promoting physical health and efficiency through organised community efforts for the sanitation of the environment, the control of community infections, the education of the individual in principles of personal hygiene, the organisation of medical and nursing service for the early diagnosis and preventative treatment of disease and the development of social machinery which will ensure to every individual in the community a standard of living adequate for the maintenance of health* (Winslow, 1920 cited in Verweij and Dawson, 2007).

Clearly the focus is on a narrow and mechanistic conception of health as a physical phenomenon but the notions of community, social justice, the greater good, aggregate thinking, preventative and sustainable practices resonate with the vision and ideologies of contemporary public health.

Definitions of health as 'the absence of disease' permeated thinking in the health domain for much of the 20th Century. Similarly, the construction of public health as a matter limited to health services overshadowed policy in the Thatcher regime of the 1980s. At this time, public health strategies tended to focus on individual behaviour change, lifestyle causes of disease and the framing of health as a commodity. In the past two decades there has been an increasing recognition of the 'complexity' of health and its inextricable links to larger social, environmental, economic and political processes which has taken the emphasis away from behavioural factors and the detrimental blame culture in health (Scally, 1998). Bunton and Crawshaw (2006, p.1) describe a trend to visualise and represent health using more abstract and ephemeral constructions, which are commensurate with the *"flows"* and *"interactions"* of people and information.

The World Health Organisation's definition of health as "*a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity*" (WHO, 1948) is still current and commonly referred to in public health discourse, although it is sometimes criticised for being naive and idealistic (Hunter, 2003a). The plethora of definitions appropriated to health are shaped by different value systems, beliefs and assumptions. To foster good working

[1] The use of the term 'boundaries' is perhaps ambiguous in a thesis employing complexity theory within its theoretical base. It is recognised that public health is a broad phenomenon with fuzzy boundaries, however there is a need to lay down some kind of parameters with which to constrain the breadth of the thesis.

practice in public health, Seedhouse (1997) urges the need for clear and transparent definitions, which in turn requires that underlying values are made explicit. Concerned about the ambiguity regarding explanations and understandings of health and public health Beaglehole *et al.* (2004) suggest that a more concise definition is needed for modern praxis. They define public health as "*collective action for sustained population-wide health improvement*" (Beaglehole *et al.*, 2004, p.2084).

Due to the nature of public health as a multi-faceted and boundary less phenomenon, it has been described as "*everyone's business*" (Department of Health and Social Security, 1976). As Littlejohns and Kelly (2005, p.793) assert however:

> *The premise that public health is everyone's responsibility has often meant that no one has taken responsibility for its implementation in a complex and fragmented environment.*

Drawing on historical precedent, public health policy is beginning to recognise the role of non-medical specialists in developing a multi-disciplinary workforce for action at a local level (Evans and Dowling, 2002; Gorsky, 2007). McPherson (2001) contends that a medical hegemony has no place in public health since it is widely accepted that health is much more than simply the absence of clinical disease. Yet as McPherson argues - using the coronary heart disease national service framework (NSF) of 2000 - there is still a bias in government funding towards clinical care rather than preventative strategies.

Despite the dominance of the biomedical model in past decades, which relies heavily on Newtonian ideals such as reductionism, empirical observation, and neutrality, public health is beginning to work across boundaries and to understand the system as a whole (Hunter, 2003a). Policies are becoming less myopic by considering the 'determinants of the determinants' or "the causes of the causes" (Gabbay, 1998, p.487) such as poverty, social exclusion and unemployment to produce organic and joined up solutions to complex and inter-connected problems (Department of Health, 1998). In line with the findings of the Acheson Inquiry and the Wanless Report, there is a drive to reduce persisting inequalities and to work up stream on the distal social, political and economic determinants of health. Such a strategy requires what Wanless has termed 'a fully engaged scenario' (Wanless, 2002), the most favourable of three possible scenarios which puts the onus on preventative cost saving strategies (Hunter 2003b) to challenge the prevailing biomedical care/cure orthodoxies.

1.3 Mapping and health

Boulos, Roudsari and Carson (2001) observe that the relationship between location and health was understood by physicians back in the 3rd century BC at the time of Hippocrates. According to MacKian and associates (2003) maps are more than simply a series of points, lines and polygons (see quote p.1). Cartographic maps have a multitude of functions and uses: historically, maps have been used in defence, for navigation and in World War II cartoon maps were utilised for propaganda purposes (Monmonier, 1996). Harley (1989) asserts that maps are associated with a positivist epistemology as they are viewed as an objective form of knowledge.

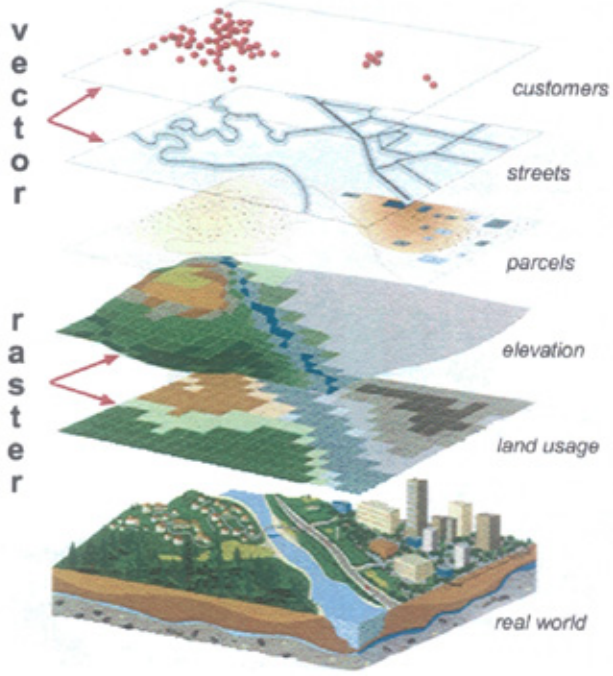
John Snow was the first public health practitioner to use maps as a form of evidence to demonstrate the spread of disease and challenge current thinking at the time regarding transmission of infection. By mapping cases of cholera in relation to a contaminated water source, Snow was able to disprove the commonly held miasma theory of disease. Just a few decades later, Charles Booth relied on the use of mapping in his seminal inquiry into social deprivation in London. The work (*Life and Labour of the People of London*) was undertaken between 1889 and 1903 and comprised 17 volumes (Dorling *et al.*, 2000).

Drawing on Booth's work, Dorling and associates (2000) were able to demonstrate, using a GIS mapping approach, that health inequalities remain ingrained in society over time. They compared today's patterns of deprivation in inner city London with historic maps of the same area in the 1890s and were able to demonstrate that very little had changed. Mortality from disease known to be associated with poverty in early life such as coronary heart disease, stroke, stomach and lung cancer were correlated with deprivation and in some cases were more strongly related to poverty in the late 1800s. The spatial patterning of deprivation was remarkably similar when the map epochs were compared (perhaps due to a stable transport infrastructure and a continuing flux of migration). Thus demonstrating how little has changed over time and that the origins of some current diseases can often be rooted in the past.

As part of the Information Revolution technologies such as geographical information systems (GIS) have emerged as vehicles for the storage, management, integration, analysis and presentation of spatially referenced data (Schuurman, 2004). GIS have applications in fields as diverse as engineering

and anthropology (Heywood, Cornelius and Carver, 1998). In this study the concept of data integration (see figure 1.1) is examined as a parallel to the key public health notion of collaboration and data sharing. As Beaglehole and co-authors (2004) recognise public health issues are dependent on time and place. GIS mapping approaches are therefore well suited to make conditions of time, space and place explicit.

Figure 1.1: An example of a geographical information system (GIS) integrating raster and vector data[1])



(Source: Environmental Systems Research Institute, 2000)

1.4 Complexity theory

Complexity has long been referred to implicitly in public health discourse (public health issues are often described as complex or thorny) but it is only in the past decade that the concepts on complexity theory have been directly applied and drawn out within the health domain. Few published papers exist which explore the application of complexity theory in the specific context of public health. Much of the progress in this area has been through conference discussions and networking. The study presented here aims to apply concepts from complexity theory to the understanding of mapping technologies in the

[1] GIS store data in raster or vector format. Raster refers to data represented as a matrix of cells or pixels in which the order of cells determines spatial position, whereas vector data includes objects represented as points, lines or polygons referenced to a co-ordinate system (McDonnell and Kemp,1995).

public health arena.

The complexity paradigm emerged in the 1970s and early 1980s in the natural sciences (Cooper, Braye and Geyer, 2004) as a response to a preoccupation with mechanistic and reductionist ways of knowing and doing. The language of complexity has filtered through into the health domain but concerns regarding the use of the complexity paradigm in a superficial capacity are apparent. Complex adaptive systems range from something as simple as a pile of sand (Papadopoulos *et al.*, 2001) or a pendulum (Byrne, 1998) to larger and grander entities such as weather systems and the immune system (Stacey, 1996). A number of commonalities distinguish a complex adaptive system and include the properties of:

(i) emergence (adaptability and sensitivity to environmental conditions);
(ii) open systems;
(iii) non-linear interactions;
(iv) feedback systems.

Each of these properties are discussed in detail in section 3.2, chapter 3.

To reflect on a topical example, the H5N1 virus, implicated in the aetiology of bird flu, is itself a complex adaptive system. The virus is composed of relatively simple structures, which exhibit an array of far more intricate and subtle behaviours to affect the system at micro, meso and macro levels. The haemagglutin and neuraminidase proteins facilitate binding to the host cell and serve also to protect the virus' replication machinery (the RNA core). Once the virus attaches to the host epithelial cell, sophisticated feedback mechanisms signal for the process of RNA replication to begin (Mims *et al.*, 1995). If the virus is unable to attach and penetrate the host cell, replication cannot occur and the virus, a parasite, is unable to survive without the host cell's machinery. The virus is open to the effects of its environment and exhibits flexible patterns of behaviour to enable survival and propagation. Whilst some of the behaviour exhibited by the virus could be described as linear, the capacity of influenza viruses to combine with other strains resulting in antigenic shift or antigenic drift is unpredictable and disordered. The combination of random or chaotic behaviour and replication through rapid and simple processes results in evolutionary beneficial outcomes for the virus.

Whilst in some quarters complexity science is seen as the beginnings of

a paradigmatic shift, other camps (perhaps due to an entrenched philosophical approach) view complexity as a transient model that is currently in fashion. The value attributed to complexity approaches tends to depend on how it is framed by the audience (Manson, 2001). In contrast to work by Papadopoulos *et al.* (2001) and Walsh *et al.* (2007), all of whom adopted mathematical approaches to modelling complexity, this thesis uses complexity theory to facilitate conceptual understanding of decision-making systems in public health practice. It is difficult to map a complex phenomenon using a simple linear model. Any attempt to do so would neutralise the intricacy of the scenario. As Haslett (1992) maintains that:

> *The inter-relationships between diverse forms of data can be complex. The spatial decomposition of these relations is a vital part of the integration* (Haslett, 1992, p.271).

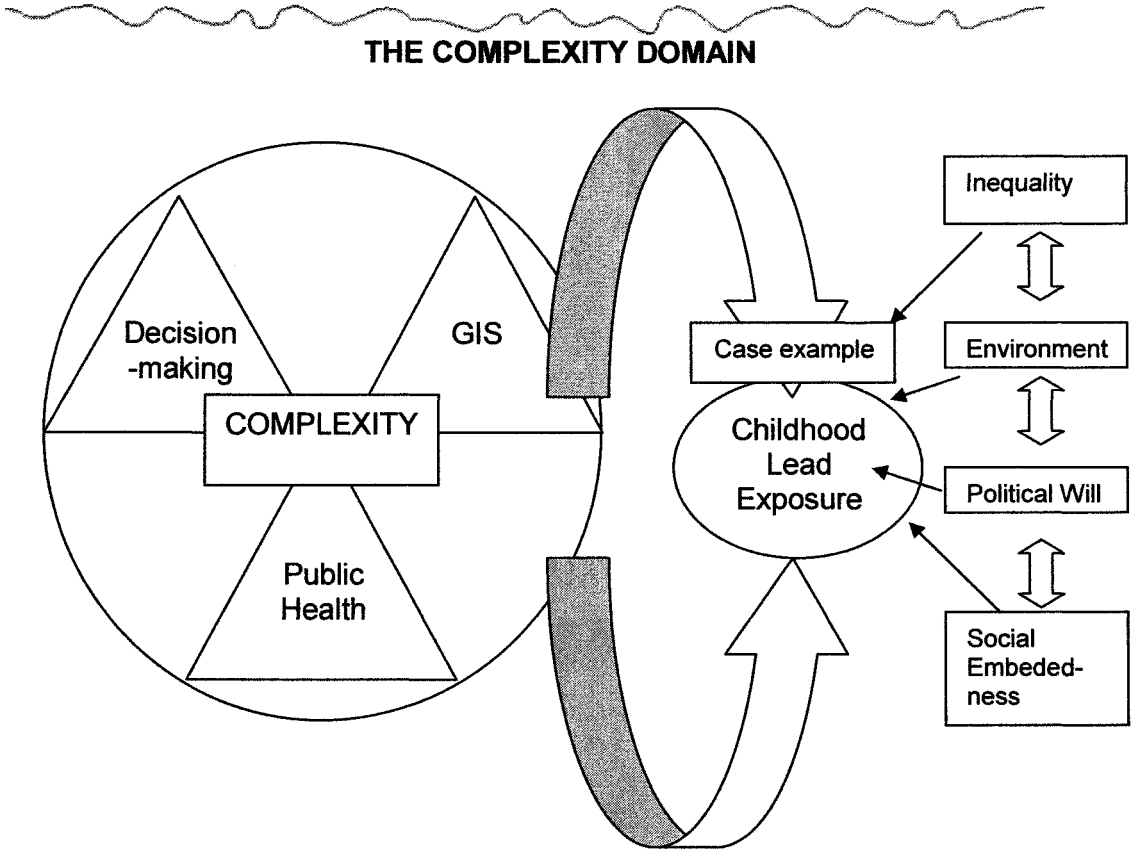
The central themes of complexity: inter-relationships, contingency, elements of order and disorder, paradox, unpredictability and emergence are highlighted in figure 1.2 and will be discussed in further depth in chapter 3, Complexity and Public Health.

1.5 Study rationale

Despite its introduction to the NHS in the 1980s the application of GIS remains localised often limited to use in information management (see chapter 2, section 2.16 and chapter 4, section 4.2.2 for further detail). With the exception of work by Dunn *et al.* (2007) few examples exist to demonstrate the use of GIS in public health decision-making pathways. Back in 2001, Higgs drew attention to the lack of widespread GIS uptake and later in 2004, Cockings highlighted that GIS applications remained limited in the health sector. So what are the reasons for low uptake? Cockings *et al.* (2004) conducted a study using a questionnaire based approach to address such questions. Their findings demonstrated that although knowledge was reasonably good of basic GIS concepts, more sophisticated applications of GIS were rare.

In response to Derek Wanless's call for information and intelligence on the health status of the population, the government is seeking to secure the provision of high quality data to all those involved in public health practice (Raine, Godden and Mckee, 2006). With this in mind the time for GIS surely is here.

Figure 1.2: Defining the boundaries of the thesis



1.6 Contribution to knowledge

There is a paucity of information relating to how geographical information systems evidence can be used in public health. The current government advocate evidence-based policy and practice but little is known about how GIS technologies can contribute to decision-making processes. An issue with an inherent spatial dimension, childhood lead exposure, is used to demonstrate both the benefits and limitations of using GIS to manage, integrate, manipulate and communicate data for decision-making processes.

The study is firmly rooted in the public health context. Decision-makers working in the public health community need to know whether GIS is something that should be incorporated into the evidence toolbox for decision-making. Are maps valid sources of evidence? Is GIS a valid tool for public health practice? Questions also arise as to whether a GIS expert is needed to undertake analysis or whether decision-makers with a clear understanding of the complex nature of public health issues should be trained to utilise GIS. The term

decision-makers refers here, to those people who have the potential to influence public health policy. It includes personnel from statutory and regulatory agencies as well as from those organisations with a specific public health remit. The point of departure is expressed in the study aim and objectives.

1.7 Study aim and objectives

Aim: Through the use of the case study approach the project aims to explore how GIS data can contribute to the evidence base for decision-making in contemporary public health. Childhood lead exposure represents the case example within the context of Newcastle upon Tyne.
The following research objectives were devised to achieve this central aim:

1) Produce visual representations of potential childhood lead exposure by mapping discrete environmental and demographic datasets using GIS. Through objective 1 understand the principles and nuances of the GIS toolbox and produce stimulus material for debate with decision-makers.

2) Conduct a series of semi-structured interviews with decision-makers in agencies whose work impacts on the public's health, to explore their thoughts, perceptions and beliefs concerning the value of GIS in public health.

3) Through analysis of interview transcripts examine and unpick:
   - the status of GIS as a tool within public health organisations;
   - the value of GIS map representations in the evidence base for decision-making;
   - the use and possible misuse of maps as evidence;
   - the potential of GIS to act as a vehicle for information sharing to facilitate inter-agency collaboration.

The study aim and objectives guided the study design as discussed below and shown in figure 1.3.

1.8 Study design

The study employs an eclectic approach towards methodology, incorporating a GIS mapping exercise coupled with qualitative interviews within a case study design. A qualitative design was believed to be most relevant due to the nature of the study questions, which were: to explore how public health decision-makers valued GIS technologies in their practice and how they perceived maps as evidence in decision-making processes. The GIS mapping phase involved collection and secondary analysis of quantitative data on the complex case issue of childhood lead exposure. Analysis of the GIS maps overlays informed and shaped the questions for discussion with decision-makers in the interviews. In the thesis the case issue (potential childhood lead exposure) represents an example of the 'case', which is defined as 'decision-making in public health'.

The case study crosses the disciplinary divide both intellectually and pragmatically. The mapping of environmental and population data using GIS represents a novel and potentially useful way of integrating disparate sources of data. The reasons for undertaking the mapping exercise were two-fold:

(i) to enable the researcher to develop understanding of the nuances of the GIS toolbox.

(ii) to produce a mapping report with which to engage participants and to provide stimulus material for debate within the interview context.

The interview phase considered how GIS data are interpreted and whether presentation of data using GIS may enhance knowledge to empower key decision-makers involved in public health. With these ideas in mind, important considerations addressed included: (i) how participants valued GIS technologies as a means to produce novel visual presentations of public health data for decision-making; (ii) the capacity of participants to interpret or even misinterpret GIS evidence and (iii) how individuals perceived GIS mapping as a means to engage with others and to work within a common dialogue using maps. Due to the diverse sample of organisations approached for interview (see section 1.7.1) difficulties were encountered in framing the questions and interpreting participant's responses. These issues related to the way individuals valued evidence, which were in turn shaped by their world-view and the ontological and epistemological positions of their organisation. The study

sought to examine the concept of interdisciplinary working by considering the prevailing cultures, ideologies, territorial positions and organisational didactics of the agencies involved, in an attempt to understand the factors that might act as promoters or barriers to effective collaboration.

Case study is an appropriate methodology as it allows the researcher to investigate the full extent of the context sensitive case *in situ* (Stake, 2003). It should be emphasised that potential childhood lead exposure is used as a case example to examine the contribution of GIS to the evidence base for public health decision-making. The study was not concerned with investigating issues around causality in terms of environmental lead and its physiological effects, rather the phenomenon of interest is public health decision-making.

1.8.1 Everybody's business: organisations selected for interview

In accordance with the notions of inclusivity and an all encompassing definition of public health (Kelly *et al.*, 2002), a broad range of organisations were invited to participate in the study. Of those organisations approached a number were from the public sector and included those in local and central government (the Department of Health; Government Office North East [GONE]; Health Protection Agency North East; Newcastle Local Authority; North Tyneside Local Authority and South Tyneside Local Authority as well as government funded agencies and sections of the Regional Development Agency namely: Durham and Tees Local Strategic Partnership; North East Regional Information Partnership (NERIP); the North East Assembly and Sure Start. Agencies represented from the environment sector included the Environment Agency and Northumbrian Water Limited. Academic institutions (The University of Durham, The University of Newcastle and the University of Northumbria at Newcastle) were invited to participate to capture the opinions of active researchers in debate on issues relating to health, space and place.

Finally a number of NHS associated organisations were recruited including: Access to Learning for the Public Health Agenda (ALPHA); Gateshead Primary Care Trust; Newcastle Primary Care Trust; North Tyneside Primary Care Trust; Northumbria Healthcare Trust; Northumbria, Tyne and Wear Strategic Health Authority; Sedgefield Primary Care Trust. Agencies were chosen to reflect the breadth of organisations involved directly or indirectly in the public health agenda. Drawing on complexity theory, the sampling

framework attempted to echo the existing or potential relationships between agencies at local, regional and national levels that impact on public health.

1.9 Introducing the case example: potential childhood lead exposure in Newcastle upon Tyne

Contemporary international research has associated the heavy metal lead (Pb) with loss of cognitive development and behavioural problems in children and has shown that exposure and uptake are related to socio-economic status (Canfield *et al.*, 2003; Tong *et al.*, 1996). The health effects of lead are not distributed evenly throughout different socio-economic groups and children with pre-existing nutritional deficiencies living in areas with multiple sources of lead contamination tend to be disproportionately affected (Centers for Disease Control and Prevention, 2000).

In the UK there is a dearth of up to date epidemiological studies on the risk of lead to children. Furthermore, there is little evidence available to demonstrate the unequal distribution of lead geographically and throughout the social strata. This study attempts to provide some preliminary descriptive data on the distribution of lead, from a range of disparate sources, throughout Newcastle upon Tyne. The value of these maps will then be discussed with decision-makers involved in contributing to public health policy. Participants will be asked about the origins, value, status and usefulness of the GIS maps. The reader is reminded that potential childhood lead exposure is the case example in a study whose central aim is to examine the value and utility of GIS presentations in the evidence-base for public health decision-making.

Urban areas of the North East have been associated with high levels of heavy metal contamination, a legacy of industrialisation. Areas with the highest levels of contamination correlate with those areas supporting the most deprived communities. In Newcastle, 56 out of a total of 173 super output areas (SOAs) are within the most deprived 10% of SOAs in the country (Newcastle Partnership, 2007, p.67). Potential long term exposure of the population to contaminants, such as lead, could therefore be a significant problem in Newcastle upon Tyne as well as other areas of heavy industrialisation.

The study is a collaborative venture in itself, involving support and advice from the Health Protection Agency North East. The mapping phase of the study was supported by the Newcastle Lead Task Force Group, an interagency

working group involving representatives from the Health Protection Agency North East, Newcastle City Council, the Northumberland and Tyne and Wear Strategic Health Authority, Northumbrian Water Limited and the Universities of Newcastle and Northumbria. The Newcastle Lead Task Force highlighted a need to discover whether or not lead was a public health problem in Newcastle upon Tyne. As well as contributing to local knowledge, the results of the PhD study presented here were fed back to the Lead Task Force Group to inform the design of further analytical studies.

1.10 Structure of the thesis

The thesis is presented in two volumes (Volume I, the Thesis; Volume II, the Appendices) as a practical measure to facilitate easy comparison between text and map overlays. Graphic displays and diagrams are presented throughout the thesis to echo the notion of maps as vehicles for integrating information and as strands of evidence for critical debate.

This introductory chapter has served to contextualise the study and set out the main themes for exploration, which will be underpinned throughout the thesis by the complexity paradigm (see figure 1.3).

Chapter 2, the Literature Review, examines and appraises the current body of knowledge with respect to models of decision-making and the use of evidence within the public health domain.

The theoretical approach is laid out in chapter 3, Complexity and Public Health, in which the concepts of emergence, order/disorder, attractors, contingent relationships, and paradox are discussed in relation to the case study. The chapter attempts to legitimise the use of complexity theory by making explicit the links between the conceptual framework, the case issue and the methodology employed

Chapter 4, Methodology and Methods, defends the use of the case study approach and discusses the evolution of the mapping and interview phases of the study.

The approach to analysis is outlined in chapter 5, Data Analysis. The chapter describes the use of Microsoft Word and Excel in the analytic strategy, which was conceptually driven by the tenets of complexity theory.

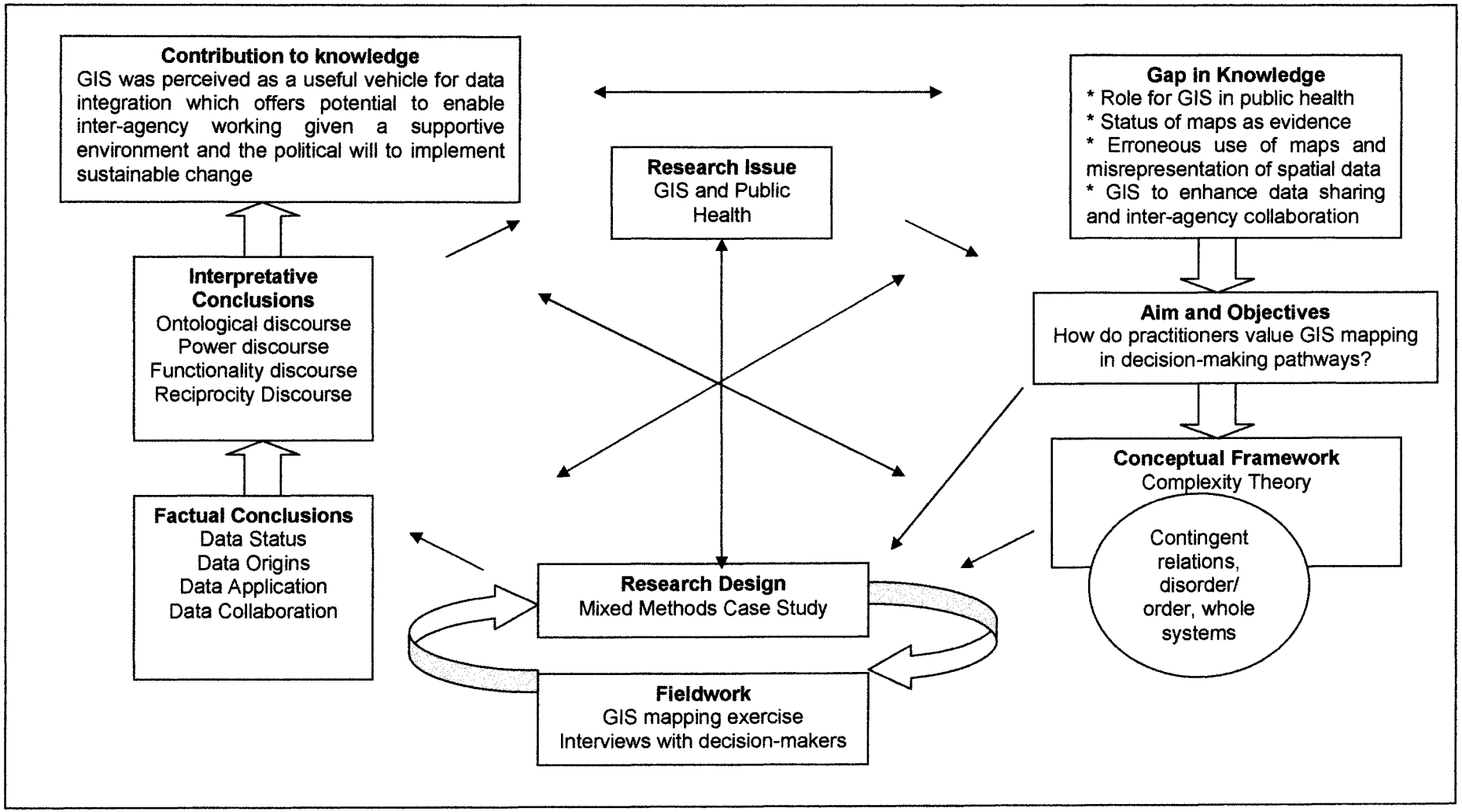
Chapters 6 and 7 explore the study findings. Chapter 6 (GIS mapping of data relating to childhood lead exposure) is concerned with the process of map

making and the participant's reactions to the mapping report. While chapter 7 (GIS technologies and maps as evidence) unpacks the interview material by drawing on the ontological, power, functionality and collaboration discourses.

Much of the interpretation of the study findings is located in chapter 8, the discussion, which draws together the main themes of the study in critical debate. This chapter is structured using constructs pertaining to the complexity domain and discussion makes links with the existing literature base.

In the final chapter, the conclusion, the major findings from the study are reiterated and the limitations of the study are set out, along with suggestions for further research.

Figure 1.3: Diagram to show the structure of the thesis from a complexity stance highlighting the importance of the two-way relationships between components (adapted from Trafford and Lesham, 2004).



"There has been a tendency in this fiercely managerial and technocratic age to reduce problems to technical ones and in effect to depoliticize them. So defects in the evidence base can all too easily become an excuse or a pretext for inaction."

(Hunter, 2003a, p.23).

Chapter 2: Literature Review

2.1 Introduction

Bell (2005) describes the foundations of a literature review as a map of how research will be conducted and analysed. Building on this notion, current knowledge and understanding will be mapped out and unpicked to determine gaps and possible inadequacies in the contemporary literature base. In accordance with the broad conceptualisation of public health adopted throughout the thesis, a range of literature bases were searched (see figure 2.1) including health, science, environmental and sociological databases using both keywords and MeSH subject headings for the health databases. In addition, specific web based searches were carried out and a number of articles were identified through dialogue on discussion boards. Environment and geography orientated databases were searched first before moving the foci toward the sociological and health literature.

This chapter examines and appraises the literature base in relation to the use of GIS mapping in public health decision-making processes. The purpose of the literature review is threefold. First, it serves to contextualise the study within the public health domain. Second, it attempts to critically appraise the current literature base with respect to the adopted methodology. Finally the literature review seeks to provide justification for the use of complexity theory as the underpinning conceptual framework for the thesis. These 'purposes' find expression in three inter-related sections.

The first section addresses the principles of public health decision-making, which is explored through a number of different frameworks. This section opens with a general over-view of the public health context in which the study is embedded. Various models of decision-making in public health are described and critiqued and the growing movement towards evidence-based approaches is dissected. The second section explores the use of evidence as a driver for decision-making. Relevant literature is appraised and a critical survey of current knowledge, methodologies and research developments is synthesised. The third and final section draws the initial debates together by examining GIS as a tool for decision-making and maps as legitimate sources of evidence. The usefulness of complexity theory emerges as the discussion traverses decision-making contexts and pathways. The chapter will foster links

with the existing body of literature to demonstrate the thesis's novel contribution to knowledge whilst drawing attention to the timeliness of the study.

Table 2.1: Sources accessed for review

Source	Detail
Health Databases	CINAHL, Medline
Science Databases	Sciencedirect
Environmental Databases	Geobase
Sociological Databases	Web of Knowledge, IgentaConnect, Blackwell Synergy
Internet searches	Detailed searches using specific key words
Evidence Network Discussion Group	www.evidencenetwork.org Expert advice and recommendations

2.2 Public health: the historical context

Public health policy was shaped by the work of Chadwick and the sanitary reformers who identified the relationships between disease, poverty and poor sanitation. The 19th Century saw a variety of theories surrounding disease causation including miasma, contagion, behaviour and supernatural hypotheses (Raphael, 2000). In the early 20th Century there was a paradigm shift towards biomedicine (Ham, 2004) and therapeutic care with the advent of antimicrobials and widespread vaccination strategies to service the 'need for a pill for every ill' (Showalter, 1987). Up until then the focus had been on the health of the population and more specifically on the social, political and economic determinants of health.

In the international policy context the importance of public health was not forgotten, with the WHO launching the proposal 'Health for all by the Year 2000' in the Alma Ata declaration (1978). Although viewed by many as being overly ambitious, the underpinning ethos of the project was the recognition of the wider determinants of health and the adjustment of the focus of public health to areas outside of biomedicine. The Ottawa Charter reaffirmed the cross-cutting nature of public health and the need for engagement, responsibility and accountability throughout all policy arenas:

> *Health promotion goes beyond health care. It puts health on the agenda of policy-makers in all sectors and at all levels, directing them to be aware of the*

health consequences of their decisions and to accept their responsibilities for health (www.who.int/hpr/NPH/docs/ottawa_charter_hp.pdf).

Although criticised for being largely theoretical and difficult to interpret on the ground level, the charter served to highlight the importance of structure and policy in influencing the health of populations (Beaglehole and Bonita, 2004).

In the UK, however, the focus of health care policy was orientated towards the biomedical model: provision of care and treatment of disease on an individual basis. The Thatcher government endorsed individualistic determinism, focusing on behaviours and lifestyle factors, which conflicted with an understanding of the wider social, economic and political determinants of health. In 1974, the position of Medical Officer for Health was made obsolete and community health services, which were previously administered by local government, were relocated to primary care institutions in an attempt to 'de-medicalise' hospitals. Perhaps by concentrating on these reconfigurations, the UK government failed to engage with a larger movement towards an integrated understanding of public health, thus engagement with the reality of international agreements was marginalised. Or perhaps the government at that time was not ready - ideologically - to embrace a more holistic model of health.

Hunter describes the renaissance in Public Health since New Labour came to power in 1997 (Hunter, 2004) and a return to a broad and dynamic concept of health with less emphasis on therapies and biomedicine. Today, public health rhetoric is concerned with protecting, promoting and improving health rather than simply preventing ill-health. The Black Report, first published in 1982 but largely ignored by the Conservative government, has been drawn upon to shape government strategy with respect to tackling persistent inequity and inequality.

Baggot (2000) advocates the broad definition of the new public health and emphasises the importance of the underpinning multi-agency ethos, which is omnipresent in recent governmental publications. Although criticised for returning to an individualistic approach to public health (Hunter, 2005) whereby individual choice and responsibility dominate, 'Choosing Health' (Department of Health, 2004) reiterates the need for policies to be built upon sound evidence and that the themes of collaboration, inter-disciplinarity and working together remain central. Communication pathways between and within disciplines are often complex. In order to contextualise the debate an overview of the

contemporary decision-making contexts is now provided.

2.3 Contemporary decision-making contexts

Public health transcends artificial boundaries. In contrast to clinical medicine the focus is on populations rather than individuals, which frequently gives rise to paradox, contradictions and misunderstanding (for example difficulties in reconciling agent and agency). The population emphasis is resonant with complexity thinking whereby a focus on individual actors or elements is insignificant and meaningful analysis emerges by thinking in terms of the system with emphasis on the inter-relationships between actors at different levels within the whole. Contemporary public health practice aims to engage and empower communities to make sustainable change at local levels, which can be supported across time and place. Bottom up approaches are favoured as opposed to those that have been traditionally centrally driven (Evans, 2004). Beaglehole and co-authors (2004) identify five key themes for public health practice in the 21st Century as shown in table 2.2. These themes are adopted to examine aspects of public health decision-making.

There is an acceptance that change is required not only at the individual level but also across communities and society as a whole. Researchers and practitioners alike are cognisant of the broader determinants of health ('the determinants of the determinants'), which include a range of factors: from structural, economic and environmental determinants to access to services and behavioural determinants (Kelly, 2005). For example, at an individual level interrupting the pathway between source and receptor could prevent childhood lead exposure and uptake. From a population perspective, however, the focus should be on understanding the factors that shape exposure, such as deteriorating living conditions, poor diet and living in deprived communities which tend to be near to (formerly) industrialised areas.

Table 2.2: Five themes for contemporary public health practice (adapted from Beaglehole et al., 2004)

Themes	Importance and Example
Health Systems Strategy and Leadership	Long term perspective for strategic direction and monitoring of progress. Beaglehole *et al.* (2004) criticise governments for being reactionary to immediate issues rather than advocating for improvement.
Political engagement in public health policy	Beaglehole *et al.* describe how Virchow in 1848 recognised the need for connections between politics and health but there has been a resistance to the inclusion of health politics in public health discourse.
Multi-disciplinary approach	To understand the links between the proximal, intermediate and distal determinants of health. The example of coronary heart disease (CHD) is cited as an area where multi-disciplinary policies and action could make many of the deaths attributed to CHD preventable.
Collaboration	To enable equitable uptake of strategies across populations. Tobacco control is presented as an example where change was appreciated only by the most affluent, health seeking sectors of society.
Partnerships	Important to achieve sustainable change and support for policies. Moreover, it will empower communities to lobby for healthy change and improved services themselves. Many community development projects, such as local food initiatives and allotment projects represent examples of successful community engagement and empowerment.

There is a need to focus on macro determinants rather than individual level determinants (Davey-Smith *et al.*, 2001) and to work upstream to make real changes in health rather than simply in NHS health care (Hunter, 2003a). One strategy is to reduce health inequalities by focussing on the most deprived

groups especially young mothers and children with the aim of promoting equitable choice and social justice. In terms of childhood lead exposure this would make sense because, from a population health view point, the gap between those most and least at risk could be narrowed. Conversely, the gradient approach to tackle health inequalities has been suggested to circumvent the weaknesses of the latter strategy which fails to address deprived groups who fall outwith the most deprived quantile (Marmot and Wilkinson, 2006). As Marmot argues:

> *...the social gradient in health is not confined to those in poverty...It runs from top to bottom of society, with less good standards of health at every step down the social hierarchy. Even comfortably off people in the middle tend to have poorer health than those above them* (Marmot and Wilkinson, 2006)

Public health initiatives have, in the past, focussed too narrowly on individual behaviour change which has engendered a blame culture. A whole systems approach is essential to bring about change on a population level. The biomedical approach has remained ingrained within the ethos of UK public health practice, in part due to the framing of public health as a specialist arm of medicine (Beaglehole *et al.*, 2004). Hunter (2003a) observes that government thinking is beginning to embrace a whole systems approach (dialogically at least) by moving away from strategies, which dissect problems into their component parts to consider the interconnectedness of the whole. It would appear that acceptance of complexity has begun, albeit at a dialogical level.

The biomedical model is so deeply embedded within epidemiological and public health discourse that the theoretical paradigm on which many research studies are based is implicit and taken as the accepted norm (Hawkesworth, 1988). As Raphael (2000) observes few public health practitioners actually make reference to their philosophical stance or favoured research paradigm. It is rare for researchers and practitioners alike to make their inherent biases, epistemological assumptions and ontological value systems explicit. For decades the tradition of quantitative, experimental methods has been so deep-rooted in practice that such methods have rarely been questioned. There is a growing appreciation of the limitations of the biomedical approach, but its dominance still remains:

> *...its underlying ideology is expert-driven, authoritarian and disempowering; seeking evidence through narrow clinically based methods and short term quantitative outcome measures* (Davies and Macdonald, 1998, p.209).

Some progress has been made towards affording plurality to public health methodologies but the biomedical model continues to be strong and dominant in certain camps particularly where the culture is, by tradition, medical, for example epidemiology and health protection. Following from Beaglehole and co-worker's typology of public health themes (2004) the role of strategy in decision-making will be debated in the next section.

2.3.1 Strategy and public health decision-making

Decision-making in public health may be a nebulous notion due to the accepted contemporary definition of public health as a multi-faceted and dynamic phenomenon. Kemm (2006) highlights that policymakers all too often overlook the complexity of decision-making processes by trying to seek the singular 'best solution' to the issue in question. This overly simplistic approach frames decision-making as a linear process. Decision-makers from regulatory agencies and public health bodies require sound evidence on which to base their policies. Evidence is necessary to describe the extent of the problem and the complexity of the issue in terms of the interplay between social, environmental and physical factors.

Dumitrescu *et al.* (2006) argue the significance of context in decision-making processes, emphasising the importance of the dynamic interactions between social, political and environmental drivers. Sanderson and Gruen (2006) emphasise the uncertainty of decision-making in terms of stakeholder values, outcomes and boundaries of the problem. The complexity of decision-making processes within public health seems to be well appreciated although in practice there is a continuing reliance on linear and monotechnic pathways. Davies (2004) recognises that policy science requires an inter-disciplinary approach using both quantitative and qualitative methods in line with complexity discourse.

Parson (1995) provides a number of metaphors to describe the policy process: rational choice, incrementalism, the 'garbage can' model and institutional economics. Such models are fitting to visualise the use of evidence in public health decision-making. The metaphor of rational choice articulates a linear approach to decision-making whereby the problem is defined and strategies are identified, evaluated and implemented to tackle the issue (Parson, 1995; Hanney *et al.*, 2003). By way of illustration, terrorism is a

shared threat amongst the population, it can, to some extent, be defined and strategies to prevent or prepare for a terrorist attack can be planned, appraised and implemented. In contrast, the problem of mental health conditions in the population is less easy to define and effective interventions are complex, multi-faceted and un-straightforward. It could be argued that uncertainty is an inherent feature in both examples and that a linear approach to decision-making would not be suitable in either scenario. Hawkesworth (1988) states that linear models of decision-making are based on the precepts of neutrality, systematic observation, and control of subjectivity with the aim of finding a single truth to produce laws and objective knowledge.

Hunter observes, however, decision-making cannot be packaged simply as "*a rational, objective, neutral activity devoid of values or the play of power*" (Hunter, 2003a, p.18). In the real world, the politics of the process is much more complex: Hawkesworth insists that it is "*undiscernable by the senses, unresolvable by scientific techniques and dependent on subjective assessments*" (Hawkesworth, 1988, p.14). Indeed, supporters of the incrementalist model recognise that policy making is a far more complex process, which involves less tangible elements including competing ideologies, hidden assumptions, conflicting priorities and uncertainty (Parson, 1995). The incrementalist model is more in line with complexity thinking in that it is adaptive, shaped by trial and error and open to uncertainty.

The 'garbage can' model proposed initially by Cohen in 1972 suggests that problems and solutions co-exist in public discourse but many do not fit and are despatched to the 'garbage can' (Parson, 1995). Policy decisions can remain in the system despite having been deemed ineffective, unworkable or expensive (Hanney, 2003). In this manner, the process is sometimes messy and disordered. One such example is the voluntary, rather than compulsory, codes in the tobacco industry (Sengupta, 2005), which were counterproductive as they enabled corporations to prioritise profits over public health. Tobacco corporations were able to operate by employing unethical and covert tactics such as funding political parties, questioning legitimate evidence and implementing expensive public relations campaigns (Saloojee and Dagli, 2000).

In addition to the rational choice, incrementalism and 'garbage can' metaphors, Hanney (2003) describes the network approach to decision-making, which identifies the importance of relationships between different interest

groups. Within the public health sphere, clinicians are likely to influence the research agenda and determine the type of evidence that is most valued in the decision-making process. It would be wasteful and inequitable, however, to listen to only one of the many groups of stakeholders within the network. Section 2.3.2 builds on these metaphors to appraise the complex relationship between public health and politics.

2.3.2 Political engagement in public health decision-making

The relationship between politics and public health is multi-faceted and contingent. Webster (1992, p.10) discusses tensions in public health discourse and relates these issues to the *"inevitable and inextricable association with the policy process"*. Bambra, Fox and Scott-Samuel (2005) assert that health is political in four main ways:

- it is a human right;
- its social determinants are affected by political action or inaction;
- like any other resource some groups have more of it than others;
- power can be exercised over health as part of a wider system.

Bambra and co-workers (2005) observe that the politics of health are rarely discussed explicitly, despite an awareness of the effects of policy on health status. They suggest that the widespread and erroneous construction of health as health care services, or the NHS, may explain why certain health issues remain ignored in terms of the political agenda. The authors go on to support the advent of health politics as a discipline in its own right that should be incorporated into public health training programmes.

Sheard (1994) warns that public health has lost its autonomy and ability to engender sustainable change. In the same way, Hunter (2003a) suggests that issues can be depoliticized by the continuing trend to break down complex problems into linear sub-problems. Consistent with the constructs of complexity theory there is a need to understand the totality of public health issues and to consider the dynamic between actors and context in both an environmental and political sense.

Webster (1992, p.10) cites a number of interwoven issues that have impeded the evolution of public health: "*incompetence in influencing policy, passive complicity with policies subversive to the interests of public health, or facile pretence that the specialism can be isolated from direct political involvement*" (Webster, 1992, p.10).

Webster goes on to contend that the success of the Sanitary Reform owed much to their candid acceptance of the political nature of public health. Indeed, annual reports from the Medical Officer of Health in the late 19th Century demonstrate that the role of Chef Medical Officer was much broader and political and included a role in governance through the local council (Medical Officer of Health Annual Report, 1896). Webster (1992) suggests that today's public health practitioners should take heed of their Victorian counterparts by accepting the political nature of the job to advocate for the health of the populous.

> *Health is very much a political issue (with a big 'P' and a small 'p'), and will not change unless those who have political power at all levels wish it to do so and the population want it to happen and see value in it. Almost all change is wrought through people, as individuals and as groups* (Calman,1998, p. 263, cited in Hunter, 2003a).

Calman (1998) recognises the political nature of health and emphasises the requirement for engagement at all levels of the system from central to local government and with the wider community to achieve long term, sustainable change (Hunter, 2003a). To facilitate such change a multi-disciplinary approach is required; the following section will debate the possibilities for such a strategy in public health decision-making.

2.3.3 A multi-disciplinary approach to public health decision-making

Many public health issues are inherently complex and necessitate multi-disciplinary strategies to enable successful decision-making in terms of interventions and government policy. For example, the problem of childhood obesity is composed of multiple layers of individual (proximal), environmental and societal (distal) factors inextricably linked in time and place. Brownson *et al.* (2003) debate this issue by considering the behavioural factors of exercise and diet at an individual level. More importantly they also consider the upstream determinants at a societal level such as food labelling legislation, accessible and affordable markets and shops and provision of leisure facilities. A non-reductionist, multi-disciplinary approach suggests that in order to achieve sustainable change, strategies should target both proximal and distal levels of the system. So, as well as working towards structural changes at the societal level, community initiatives such as health trainers and allotment schemes are being introduced in an attempt to combat the increased incidence of obesity.

By considering the whole system and examining the 'determinants of the determinants' rather than focusing on the minutiae of the issue, more effective and long term outcomes can be achieved.

By the same token, the implications of public health policy are neither straightforward nor predictable. In consideration of the smoking ban in Scotland and Ireland, recent surveys suggest that sales of beer in public houses have decreased by 6%-7% per year respectively (Thorniley, 2007) which, at first glance, would seem like a convincing positive side effect of the national smoking cessation strategies. Interestingly, the same figures have been projected for England when the ban is introduced in July 2007. When analysing these results more closely it has been suggested that the blanket smoking ban has actually created a hidden sub-culture of smokers drinking within their own homes. It could be postulated, therefore, that the problems of drinking, smoking and associated issues (abuse, violence, anti-social behaviour) have merely been shifted from the public domain to a private setting, similar to the problem of prohibition in the USA in the 1930s.

Rather than seeking joined-up, multi-disciplinary solutions, central government could be accused of subverting responsibility and accountability in relation to deep rooted and insidious social problems by looking for quick wins in terms of public policy. Parallels are observed with the wider issue of drinking at home where it was widely reported that the government was launching a campaign to inform and discourage people about drinking to excess at home (Thorniley, 2007). It is possible that this emerging problem of drinking at home is partly attributable, at least, to the legislation on smoking in public places. People who once smoked in a social setting, while having a pint, might make the choice to smoke and drink at home.

These behaviours have wide-ranging effects as public houses often serve as community venues, which are important in maintaining social networks. The government still receives large tax revenues from sales of tobacco and alcohol, which adds to the complexity of the 'system' to improve health and introduces further paradox. From a population health stance it would be prudent to examine the inter-relationships between smoking, drinking and wider social issues to work towards more joined-up public health strategies. Drawing on the notion of multi-disciplinary working, 'collaboration' has been cited as a hallmark of public health in the 21st Century. Debate will now

consider collaboration in the context of decision-making.

2.3.4 Collaboration in public health decision-making

Beaglehole and co-authors (2004) recognise that a collaborative approach to modern public health theory and practice is of paramount importance. Inter-agency collaboration is promoted as a key way of thinking, planning and achieving sustainable outcomes in various fields including health, housing services, crime prevention, community care and child protection (Hague, 1998). There is a certain cloudiness surrounding the notion of collaboration despite it being heralded as an inherent part of modern public health practice. The concept is common in public health rhetoric but examples of good working practice are rare. Wills and Woodhead (2004) suggest that this may be due to the absence of common working values and a shared purpose within the public health workforce. Evans (2003) proposes that public health needs a long-term perspective and central government should be prepared to provide the resources to strengthen the public health infrastructure to bring about sustainable change.

Within the health care context many definitions of collaboration exist, common to most definitions are the tenets of shared values, shared goals, shared responsibility and shared commitment (Gardner, 2005; Henneman, Lee and Cohen, 1995; Nolan, 1995). Gardner (2005, online resource) observes that *"collaboration is both a process (a series of events) and an outcome (a synthesis of different perspectives)".* Like Wills and Woodhead, Gardner acknowledges that although collaboration is currently a popular idea at the policy level, it is rare that the theoretical notion filters downstream to become actual practice. This is possibly due to the absence of a common working definition but also it is likely to be due to the complexity of the process. Gardner goes on to present nine key ideas which she calls 'lessons in collaboration' to advance collaboration at a practical level. These ideas are summarised in table 2.3.

Table 2.3: Key ideas in effective collaboration (adapted from Gardner, 2005)

Key Ideas in Effective Collaboration
Make biases, values and goals explicit
Value and manage diversity
Develop constructive conflict resolution skills
Share power and recognise 'own power base'
Master interpersonal and process skills
Recognise that 'collaboration is a journey'
Understand the power of multi-disciplinary forums
Appreciate that collaboration can occur spontaneously
Balance autonomy and unity

Debates surrounding collaboration are driving new agendas in disciplines beyond public health. In the environmental sector, tradition has confined decision-making to quantitative, empirical evidence. Current professional thinking recognises that progress can only be made and evidence produced, collected and disseminated for decision-making, if agencies work collaboratively. Bottom-up, community partnerships are cited as the vehicles to deliver long term change in central government's regeneration initiatives (Office of the Deputy Prime Minister, 2004); although evidence to support their success is thin (see section 2.3.5).

Table 2.4 displays some of the benefits and barriers to collaboration in public health. Notably the barriers are more numerous than the benefits. Linkages and parallels between Naidoo and Wills (1994) conceptualisation of collaboration and the empirical findings of this study will be explored in chapter 7 along with possible areas of discord. Hunter (2003a) writes about the new 'specialist in public health' positions as a driver away from the hegemonic 'medicalisation' of health towards a multi-disciplinary and collaborative public health praxis. At the same time, however, he remains cynical about the likelihood of the medical domain relinquishing power and authority overall. Despite the resounding need for collaboration, examples in practice remain "*patchy and uneven*". Hunter (2003a, p.44) suggests that this may be a consequence of a paucity of explicit guidelines to direct practitioners on how to work across boundaries in the real world. The importance of a partnership approach, Beaglehole and associate's final theme for public health, will be debated in the proceeding section.

Table 2.4: Benefits and barriers to collaboration in public health (adapted from Naidoo and Wills, 1994, p.143)

Benefits	Barriers
Involves non health organisations to address issues holistically	Lack of commitment
Increases understanding to clarify roles and reduce competition	Professional rivalry and territoriality
Creates a comprehensive picture of needs to promote joined up thinking	Different world view and ways of thinking, measuring and doing
Pool knowledge for more accurate targeting of resources	Imbalance of power leading to exclusion of partners
Avoids duplication of work	Unequal workload/contribution
Ensures uniform, non-conflicting messages are delivered	Lack of skills, expertise and experience
Tackles the up stream causes of ill health not just the symptoms	Absence of shared goals and incentives
Generates new insight to revitalise attempts to address old problems	Poor understanding and acceptance of different cultures
Results more likely to be long term and sustainable	Unaligned priorities
Enables community involvement and potentially empowerment	Geographic boundaries
	No tangible results/outputs
	Fragmentation between partners, absence of a network of support
	No leader or authority figure to organise and delegate

2.3.5 Partnerships and public health decision-making

Within the context of public health, parallels can be drawn between the notions of partnerships and pluralism, both ideas are in keeping with the values of equality and diversity. Popay and Williams (1996) argue that a pluralist approach, where all voices are equal, is necessary to address current public health issues and this overarching framework should be reflected in research methodologies as well as in day to day practice. Dahl (1961), a major exponent of pluralism, suggests that all parties should be regarded as equal and should carry the same influence (Ham, 2004). Decisions are, therefore, made through compromise and consensus. In the NHS setting, so-called 'consensus management' involved administrators and clinicians on a supposedly even footing (Ham, 2004). In reality, decision-making tended to be influenced by doctors, which resulted in divisions within the health service. Although pluralism offers insight into the dynamics of health policy making, Ham suggests that it is a limited explanation of power and does not adequately

account for disparities between 'producer' and 'consumer' groups (Ham, 2004, p.214-215).

Examples of decision-making involving partnerships with key stakeholders outside of the traditional public health fraternity exist but mainly at the community level. To illustrate the importance of partnership working, handling of the foot and mouth outbreak was seen to improve when an open and equitable dialogue was brokered with the farming community. A cohesive partnership with the National Farmers Union assisted negotiations with farmers refusing access or blocking roads to government workers (Horn, 2001).

A methodologically sound case study (Heenan, 2004) found three central themes (strategic planning, the contested nature of partnerships and sustainability) relating to partnership working from semi-structured interviews with a sample of 16 key stakeholders. While acknowledging how communities can be successfully empowered by partnership projects, Hennan (2004) concludes that clear aims and objectives are necessary to avoid unrealistic expectations and that long term government support is essential to provide education, training research and resources.

Bowen and Zwi (2005) call attention to the difficulties involved in translating the tenets of evidence-based decision-making at the local level. Drawing on a study by the Kings Fund (Coote, Allen and Woodhead, 2004), which examined the use of evidence-based thinking in community based initiatives, they suggest that a paucity of good quality, salient evidence coupled with structural deficiencies in terms of provision for evidence application precludes the success of evidence-based practice on the ground. In consideration of a number of complex initiatives, specifically the New Deal for Communities and Sure Start programmes, Coote, Allen and Woodhead (2004) caution that experience, expertise and politics are more significant drivers of decision-making than the scientific evidence base. The authors make a number of recommendations based on these case studies including the need to discuss the "*complex and varied role*" of evidence in social programmes and the requirement for more accessible evidence to be disseminated (Coote, Allen and Woodhead, p.5). Section 2.3.6 summarises the literature and highlights some of the limitations of the current knowledge base relating to decision-making in public health.

2.3.6 Strengths and weaknesses of the existing knowledge base: decision-making

There are few empirical studies with which to engage and critically comment. Many of the studies reviewed were descriptive rather than conceptually driven and few were based on primary data and first hand observation. As Rychetnik *et al. (*2002) assert the nuances of contemporary public health are such that appraisal of evidence by study design or methodology alone fails to take into account the complex and contingent nature of public health issues.

To capture the diversity of public health, discussion has considered a range of themes or contexts: strategy, political engagement, multi-disciplinary working, collaboration and partnership approaches. Several metaphors have been suggested to articulate decision-making processes. The model of rational choice frames the process as linear and ignores context and uncertainty, while the incrementalist model incorporates the multiplicity of factors that impact on the process including assumptions, opinions, common sense, judgements, prejudices and tacit knowledge. The multi-disciplinary ('garbage can') metaphor emphasises the dynamic nature of decision-making by suggesting that both problems and solutions co-exist in time and place and change occurs when suitable connections are made. Finally, the collaboration and partnership metaphors (the network model) focus on the inter-relationships between different stakeholders in the process. Much of the literature recognises the limitations of the Newtonian perspective but few offer any practical alternative. The complexity paradigm represents another possibility for decision-making, which can lead to shared understanding and possibilities for change. Section 2.4 will now examine how evidence is used as a driver in decision-making.

2.4 Evidence as a driver in public health decision-making

2.4.1 Evidence-based decision-making

The terms 'evidence-based practice', 'evidence-based knowledge' and 'evidence-based decision-making' are ubiquitous in social science, clinical and political discourse. But what does the term 'evidence-based' actually mean and what does it contribute to the public health agenda? A frequently cited definition supplied by Sackett *et al.* (1996, p.71) describes evidence-based medicine as the *"conscientious, explicit and judicious use of current best evidence in making decisions*

about the care of individual patients".

Redman and associates (2006) highlight the origins of evidence-based practice as far back as the 17th Century in the work of Francis Bacon. They describe the challenge of evidence-based practice as the search for best available evidence in an environment of uncertainty. The current labour government advocates the importance of 'what works' over 'what's right' in terms of evidence in policy making (Davies, Nutley and Smith, 1999; Solesbury, 2001). There is, however, a general consensus that the current evidence base is not systematic and methodologically rigorous enough. According to Kelly *et al.* (2006) gaps in the evidence base exist and there is variability in the quality and 'persuasiveness' of the evidence that is available. Dumitrescu (2006) implores decision-makers to make use of best evidence rather than the most accessible evidence available. In a recent paper, Oxman, Lavis and Fretheim (2007) the use of the term 'evidence-based' is questioned in the observation that recommendations continue to be based, largely, on expert opinion rather than a robust evidence base (contrary to what is claimed by government bodies and research institutions).

Drawing on the medical context Greenhalgh (2003) proposes four models of decision-making which pre-date evidence-based decision-making. These models also have currency in the public health domain:

(i) by anecdote (reliance on expertise, experience and tacit knowledge)

(ii) by press-cutting (knee jerk reaction to recently published studies and new data)

(iii) by GOBSAT (good old boys sat around the table, reliance on expert opinion and old fashioned value systems)

(iv) by cost minimisation (economics).

Expert opinion although valuable - certainly when there is a dearth of other forms of evidence - is subject to bias and the window for which 'experts' remain 'experts' on a particular subject can often be transient. Based on ideas surrounding evidence-based medicine described by Greenhalgh (2006), table 2.5, summarises some of the commonalities of evidence-based practice in the public health context. The table documents properties of evidence-based practice by comparison with practice that is non-evidence-based

Table 2.5: What is evidence-based practice? (adapted from Greenhalgh, 2006).

EBP	NON- EBP
Judicious (bias is minimised)	Based on a limited and potentially biased sample of literature
Transparent	Opaque
Cost is not the most significant driver	Based on cost minimisation
Clear and coherent	Fuzzy, messy
Driven by a guideline development group	Based on GOBSAT (Good Old Boys Sat Around a Table), bias in selection & size of group
Rigorous and systematic	Haphazard, un-standardised
Based on tangible evidence	Based on anecdote
Integrates expertise, experience, and tacit knowledge	Relies on linear models which break down and reduce complex issues

Gerber, Lungen and Lauterbach (2005, p.1035) describe evidence-based medicine as the "*thorough and ongoing process of searching, arranging and appraising*" to convert information into knowledge. The importance of the evidence-based approach, they argue, is the notion of democratic exchange, which is facilitated by a "*hermeneutical approach*" (or "*textual criticism*") that engages and enables everyone to participate on an even level (Gerber, Lungen & Lauterbach, 2005, p.1037). The significant precepts of evidence-based thinking are not found, therefore, in the enforced order imposed by empirical observation and hierarchies of evidence but in continual and systematic engagement and assessment of the evidence base. This more flexible way of thinking is supported by the complexity paradigm. Prescriptive quality frameworks should, therefore, be adapted in terms of context, experience and expertise (Joyce *et al.*, 2007). Rather than relying on randomised controlled trials that often tend to be inappropriate, unmanageable and in some circumstances unethical, evidence should be approached using a systematic, rigorous but ultimately flexible strategy, which takes into account the nuances of the question of interest.

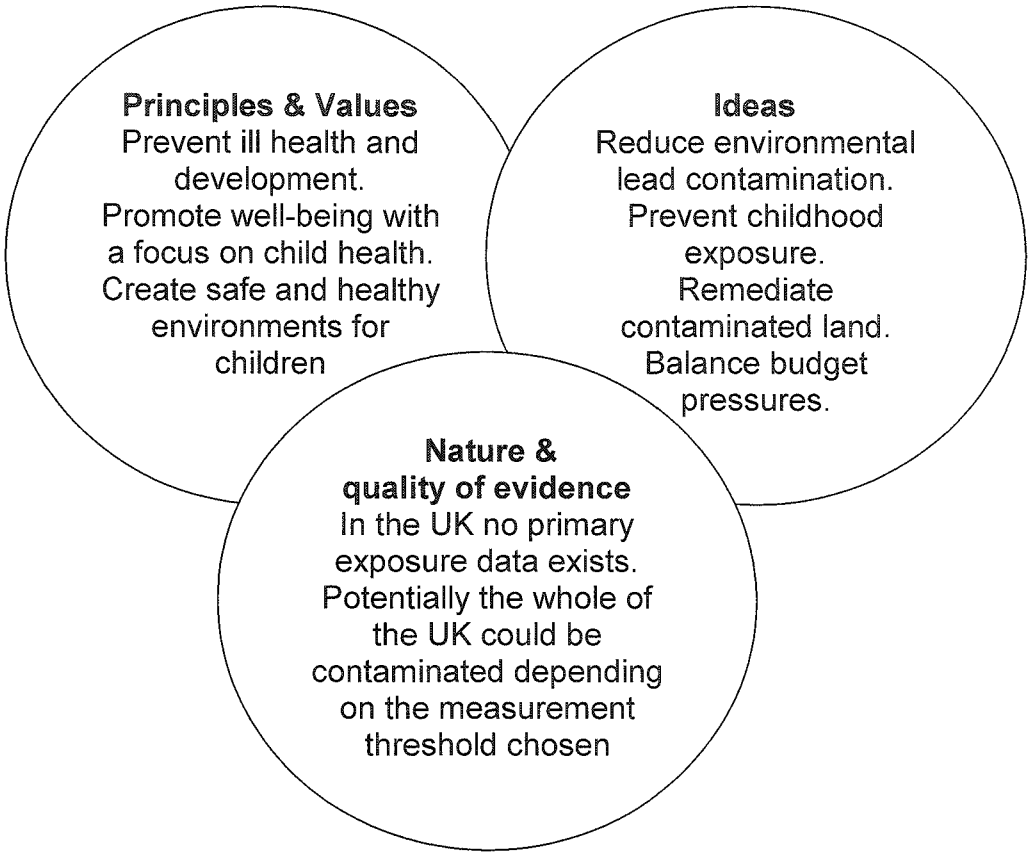
Just as "*politics is driven more by values than facts*" (Ham, Hunter and Robinson, 1995, p. 71) so too are decision-making processes in the health sector. Rodwin (2001) draws attention to factors other than evidence that affect decision-making such as training, experience, custom and parochial views. The interplay of evidence with principles, values and underlying ideology is captured using the diagram shown and adapted below in figure 2.1. Different agencies

tend to value evidence differentially and are more responsive to particular data sources depending on their organisational history, discipline, core values and previous experiences. The status decision-makers attach to particular types of evidenceseems to reflect their inherent epistemological and ontological assumptions (Davies, Nutley and Smith, 2000). An example is the strong influence of positivism amongst medical practitioners and the reliance on randomised control trials as a methodological gold standard for determining effectiveness in the hierarchy of evidence.

While positivism receives much criticism for reducing complex systems to their constituent parts and for failing to take account of context, the heritage of the positivist approach is significant and warrants further exploration and clarification. The Enlightenment period (The Age of Reason) in the 17th and 18th Centuries saw a shift away from models of thinking dominated by religion, superstition and folklore (Macmillan, 1994). The new movement was based on the ideas of rationality and reason and was influenced in England by key thinkers such as John Locke and the Scot, David Hume (Macmillan, 1994). Positivism offers many attractive features not least the notion of a value free, objective knowledge, which can be measured by systematic observation using the senses (Blaikie, 1993). During the era of the Enlightenment these ideas enabled a move towards a more free and liberal society and detachment from the tyrannical rule of the church (Macmillan, 1994)..

The influence of positivism in public health has produced many benefits. For example, simple linear strategies such as the provision of clean water and adequate sanitation have lead to a huge reduction in morbidity and mortality rates. Equally, the deduction of causality between smoking tobacco and developing lung cancer in 1950 by Doll and Hill and the serendipitous discovery of the antimicrobial activity of penicillin by Fleming in 1928 (Macmillan, 1994) serve as important examples of the success of empiricism in public health. As each research approach is valued for its potential to illuminate, methodological pluralism underpins contemporary public health research (Phillimore and Moffat 1994). From the focus on the influence of ideas, principles and values in decision-making, debate will now consider the 'types' of evidence (or knowledge) used to drive decision-making pathways.

Figure 2.1: Interplay of principles, values, ideology and evidence in decision-making practices using the case example of childhood lead exposure (adapted from Raphael, 2000).



2.4.2 Types of evidence and knowledge

Practitioners as well as policy makers are becoming more and more aware that knowledge is a resource. The complexity of knowledge pathways is articulated by Solesbury (2001, p.6):

> *Among the knowledge they need is not just 'know how' (practical experience of what works) but also know what (the state of the world), know why (causes and explanations) know who (contacts and networks). Some of this knowledge is explicit and documented but much is tacit, carried in people's heads.*

One challenge during the interviews was to unpick respondent's knowledge and tacit understandings of maps and GIS by engaging in an open dialogue. Solesbury (2001) goes on to cite organisational culture, appropriate information systems, open-mindedness to learn and adapt and notably willingness to share data and information as facilitators to knowledge management.

Systems operate in an environment of information/data overload (Dumitrescu, 2006; Fraser and Greenhalgh, 2001). Thus, there is an overt need to filter out irrelevant data and poor quality evidence, which is less than straightforward in practice. Traditional approaches to evidence collection

include deductive, experimental designs which are often controlled, with the aim of assessing causality. Conversely, there is an increasing recognition that all knowledge is socially constructed and relative (Lessard, 2007). The evidence collected to underpin many public health initiatives is limited by factors such as publication bias (studies yielding no effect or negative results are seldom published) and also by the research and funding agenda, which is skewed towards studies which produce certain types of 'accepted' research. Solesbury (2001, p8) recognises that *"evidence is more plural than research".* Similarly, Park (1993, cited in Bryant, 2002) draws attention to the different forms of knowledge in existence (see table 2.6, below). Each 'type' of knowledge will now be critically examined.

Table 2.6: Types of knowledge adapted from (Park, 1993 cited in Bryant, 2002)

Knowledge Type	Description
Instrumental knowledge	* Traditional, logical, scientific quantitative or experimental knowledge. * Controls physical and social environments. * Philosophical basis positivism and empiricism. * Uses internal and external validity and reliability to satisfy truth criteria
Interactive knowledge	* Derived from lived experiences, access to lay knowledge. * Constructivist, naturalistic, ethnographic, qualitative knowledge. * Focussed on meanings and interpretations. * Concerned with understanding and the connections among individuals. * Uses truth criteria of credibility, dependability, confirmability and transferability
Tacit knowledge	* In-expressed, incomplete or forgotten. * Difficult to access.
Technical knowledge	* Provides objectivity, neutrality and reliability. * Sometimes used in the positivist tradition but also in realist endeavours.

With regard to instrumental knowledge the randomised controlled trial (RCT) is commonly referred to as the gold standard in terms of measuring effectiveness of an intervention in biomedical research. After systematic

reviews it is believed by many to be the most robust tool for producing valid and reliable evidence. There is a growing appreciation, however, that the RCT is inappropriate in many public health scenarios because it fails to take account of context (Kemm, 2006) and the intricacies of the complex and messy real world (Macintyre and Petticrew, 2000). Furthermore, the majority of public health problems cannot easily be examined by dividing subjects into control and intervention groups. This would be unethical and immoral in many instances (for example, allocating patients to a placebo for a trial of a therapy for AIDS).

Kemm (2006) goes on to argue that complex public health issues cannot be properly understood by reducing an elaborate network of independent and dependent variables into linear measurable quantities. RCTs quantify rather than qualify, they reduce rather than expand and are too simplistic to fully appreciate the intricacies of public health problems. A plurality of methods is necessary in public health whereby heterogeneous strands of evidence are considered; not only randomised controlled trials or systematic reviews but also qualitative data from interviews, focus groups and participatory research (Fraser and Greenhalgh, 2001).

Upshur (2002) questions the need for a rigid, quantitative evidence base and reaffirms the importance of qualitative data (including knowledge, thoughts, opinions and beliefs) in understanding medical problems and issues:

> *A common theme among these approaches is the need to overcome the dualism between facts and values and appreciate the complex interplay of values, perceptions and beliefs that frame how medicine is practiced. The focus on interpretation, subjectivity, natural language and qualitative methods highlights dimensions of practice that escape the methods of EBM* (Upshur, 2002, p.116).

Similarly, Hammersley argues that qualitative inquiry is well placed to deal with "*the complex and processual social world*" (Hammersley, 2000, p.400). Drawing on work some twenty years earlier by Hargreaves (1978), Hammersley contends that his ideas are still current and applicable. Hargreaves, a proponent of the engineering model of policy making, described five functions of qualitative work that feed into the policy process, namely: the appreciative model (understands and represents views); the designatory model (facilitates participants to learn); the reflective model (illuminates and mirrors reality); the immunological model (reduces disruption and pointless change) and the corrective model (accepts complexity rather than reductionism). Although the research was undertaken in the education context the implications of the

material is nonetheless relevant to this study, which employs qualitative research methods. It is clear that qualitative modes of inquiry deepen understandings of policy-making by getting beyond the superficial to explore meaning in relation to context and experience of the major actors charged with decision-making responsibilities. These issues will be taken up further in chapter 4, Methodology and Methods.

Weir (2007) proposes a typology of knowledge in the organisational context, which includes latent and tacit knowledge, and introduces the additional category of 'subterranean knowledge'. The root of the word comes from the Latin 'tacitus' meaning silent (Weir, 2007). Definitions and uses of the phrase tacit knowledge are varied and include knowledge that is:

(i) in-expressed, 'lies in an unopened drawer', waiting to be found;

(ii) incomplete, not fully and explicitly verbalised;

(iii) lost, mislaid or forgotten (Weir, 2007).

Mohamed, Stankosky and Murray (2006) summarise tacit knowledge as the personal knowledge used by individuals to perform their work and to make sense of their world. In contrast to explicit knowledge, tacit knowledge is personal and not easily articulated (Mohamed, Stanokosky and Murray, 2006). Weir suggests that the first class of knowledge, that which is in-expressed or lies waiting to be found, should be referred to more properly as latent knowledge.

Weir also describes the category of subterranean knowledge, which is defined as knowledge that has been hidden or concealed. Intra-subterranean knowledge (within individuals) refers to personal self-censorship, which might involve rationalising untruths by lying to oneself to protect and conceal this self-knowledge (Weir, 2007). Conversely, inter-subterranean knowledge refers to the hidden, and secret organisational knowledge, which is protected by a cadre of workers within the organisation (Weir, 2007). Writing from a management perspective, Weir argues that organisations operate in degraded mode where:

> *mistakes happen, deviations from a plan occur and the consequences of a small irruption into the smooth operation of complex systems can provoke an amplified cycle of distress leading in extreme circumstances to system failure but routinely to concealment, subterfuge and deception about their normal operation* (Weir, 2007, p.8).

In the public health domain there is an acknowledgement of the importance of tacit knowledge and understanding of "*the life worlds*" of

practitioners particularly in relation to the research to practice pathway (Kelly, 2006, p.7). In terms of decision-making, in-expressed or hidden knowledge is likely to be an underlying driver, which may be purposely or unwittingly concealed. From a complexity perspective, tacit or subterranean knowledge, although open to bias, is as important as quantitative, quasi-experimental evidence and should be valued accordingly. The use of semi-structured interviews in data collection may provide opportunities to access such knowledge.

Since the information revolution technologies have been harnessed to strengthen decision-making processes. Modern technologies such as the internet, videoconferencing and computer aided software, like GIS, can be used to synthesise, review and appraise data, to provide a platform to facilitate information exchange and to minimise duplication of information and resources (Ho *et al.*, 2003). The potential of GIS in public health is discussed in depth in section 2.5. The literature review will now reflect on the potential for evidence to be misunderstood or misinterpreted.

2.4.3 Interpreting and misinterpreting evidence

Cummins and Macintyre (2002, p.436) introduce the term *"factoids"* to the evidence-based practice debate to describe "*assumptions or speculations reported and repeated until they are considered true*". Using the example of food deserts they highlight how factoids have been relied upon to inform policy decisions, in the absence of robust empirical data. The authors quote an example where they believe that evidence was used erroneously in relation to a small-scale study of differences between the cost of a healthy and unhealthy basket of food in both affluent and deprived localities in Hampstead. The unhealthy basket was cheaper on average in both the deprived and affluent areas but both types of basket were cheaper in the deprived areas. The totality of the data is seldom reported and the fact that a healthy basket of food is proportionally more expensive than an unhealthy basket in deprived areas when compared with affluent areas is the 'factoid' that is disseminated, reproduced and cited as evidence in publications elsewhere (for example in the Acheson report, 1998).

Without denying the existence of food deserts *per se* or even the robustness of the primary data, Cummins and Macintyre (2002) question the way the data were interpreted, reproduced and reinterpreted which seems to

have resulted in spurious conclusions in this particular instance. They contend that because the theory is attractive, socially sound and in no way contentious (unlike the case of risks associated with MMR vaccination) few studies are conducted to drill down into the issue further to corroborate the so-called evidence. There appears to be little urgency to conduct further studies with increased sample sizes and rigorous methods in other geographic areas (Cummins and Macintyre, 2002). The authors go on to urge caution in circumstances where there is a paucity of reliable evidence and encourage a more critical appraisal of the available data, especially where they are seen to fit conveniently with current feeling, public opinion or political expectation.

Based on Cummins's and Macintyre's study it is clear that the processes of selecting or 'cherry picking' evidence, misinterpreting data and ignoring context are real and troublesome issues within public health discourse. Then again it would be a mistake to deny evidence just because it fits with popular opinion. In fairness, they conclude that the main message for the evidence-based movement should be:

> *when making any health policy (or other) decisions, we need to move away from an unquestioning acceptance of conventional wisdom and expert advice and cast a more critical and objective eye over the facts* (Cummins and Macintyre, 2002, p.438).

To summarise, policy makers need to accept the complex nature of public health problems instead of looking for short-term, politically popular solutions. Section 2.4.4 will explore the potential for data and evidence to be used inappropriately.

2.4.4 Erroneous use of evidence

Hammersley and Gomm (1997) point to a tendency for researchers to present false results to support vested interests (either ideological, political or practical). Using the examples of sexual health, drug misuse and food risks, Bunton and Crawshaw (2006) debate the media as a source of understanding and misunderstanding relating to health issues. Consequently these possible misrepresentations of contentious issues can directly affect construction of public knowledge and understanding. While not engaging with the complexity debate explicitly, the authors draw attention to the 'complexities' involved in the construction of public health issues which are directly affected by information flow from the media and other information industries (Bunton and Crawshaw,

2006). Beaglehole and co-authors (2004) recognise the complexities of information flow and knowledge construction and propose that political engagement in public health policy should be facilitated through co-operation with the media.

Building on the theme of misinterpretation of data, Tufte (1997) explores the use of visual and statistical evidence in decision-making by comparing two examples from both ends of the spectrum of successful information display. The first example draws on the seminal epidemiological study by John Snow, which illustrates the power of paper maps in making decisions that changed public perceptions and facilitated policy reform. Conversely the second example describes the ineffective display of data relating to potential safety problems associated with the Challenger Shuttle, which lead to a catastrophic failure and the deaths of seven astronauts (Tufte, 1997).

Snow's work was revolutionary in demonstrating the distribution of cholera cases in a discrete locality in London in the 1850s, which enabled better understanding of disease aetiology and consequently, disease prevention strategies. The use of simple epidemiological spot maps showed that cholera cases were concentrated in streets served by a particular pump on Broad Street. Through basic disease detective work, Snow showed that this pump was fed by water downstream of a sewer outflow into the Thames, thereby proving that cholera was in fact a water borne disease and providing evidence against the commonly held miasma theory of disease. Snow's story captures the power of the humble map to present data in a simple format for communication and advocacy purposes.

In contrast, the Challenger space shuttle disaster represents an instance where data were misrepresented and mis-communicated in a politically charged and bureaucratic atmosphere resulting in ill-informed decisions being made. The design engineers opposed the launch due to concerns that the O-rings of the booster rockets would not seal at the low temperatures predicted for the launch date. Data to support the decision not to launch were faxed to NASA but were deemed inconclusive. Tufte (1997, p.42-44) suggests that error in data presentation such as displaying "*thin*" and incomplete statistics and the partisan or hurried selection of data accounted for the failure to stop the launch. Furthermore, engineers were criticised for thinking causally but not displaying data causally to support their arguments. Tufte (1997) speculates that the

problem was compounded by a lack of understanding and ineffective communication as engineers and administrators operate in different settings that are shaped by divergent realities and priorities.

When reflecting upon the information/understanding debate within the public health arena, the idea of plurality and listening and learning from multiple disparate voices is reinforced. Questions arise concerning what constitutes reliable evidence and whether or not the evidence-based paradigm can work in public health. Raphael (2000, p.356) contends that "*evidence is needed to reduce uncertainty in decision-making*" and goes on to suggest three propositions affecting evidence within the field of health namely:

(i) the unresolved debate surrounding 'evidence', what it is and what it is not;

(ii) prevailing ideologies influence what is deemed to be valid evidence;

(iii) local evidence is as important as government drawn nationally framed evidence.

Kemm (2006) concludes that evidence-based public health has much to learn from evidence-based health promotion. Specifically, by looking beyond reductionist ways of knowing to both interactive and critical knowledge, the perceptions and constructions of individual stakeholders can be taken into account. An appraisal of the strengths and limitations of the evidence-based approach to public health now follows.

2.4.5 A critique of evidence-based thinking

Kemm (2006) notes complaints regarding the evidence-based movement in a number of areas under the umbrella of public health. In the medical context evidence-based practice has been criticised for failing to take into account the experience, knowledge and values of both patients and clinicians in clinical decision-making. Similarly, health promotion experts have been disparaging of the reliance on traditional positivist methods of enquiry, which fail to capture the lived experience and the perceptions and understandings of communities important to health promotion strategies (Raphael, 2000). In keeping with contemporary understandings of public health, Raphael urges a focus on populations rather than individuals. Again the RCT does not represent the most appropriate research strategy for exploring population health issues. Steinberg and Luce (2005) also question the label 'evidence-based' and examine what is

needed for this label to be applied. They speculate that "*there is much variation in the validity of health care-related decisions, judgements and recommendations that claim to be evidence-based*" (Steinberg and Luce, 2005, p.92).

Kelly *et al.* (2002) caution that evidence-based thinking is subject to criticism from the social science community on two counts. First, drawing on Foucault's arguments, science is a means of exerting power and control so any attempt to draw together a public health evidence base could be perceived as a form of manipulating and controlling the very people it is setting out to help. Second, evidence-based practice might be framed as a positivistic tool, which threatens to ignore and disenfranchise the human 'voice' (Kelly *et al.*, 2002, p.9). The authors recognise that knowledge is a form of power but rather than furthering capitalist interests, this knowledge can be used to bring about change. The cynics who are quick to dismiss evidence-based approaches for these reasons are unlikely to propose any practical alternative (Kelly *et al.*, 2002).

With respect to decision-making Rodwin (2001) recognises that it is impossible to control for and separate out issues relating to values, power, place and politics. Furthermore, he suggests that in the United States there is a need to search for a "*technocratic fix*" (Rodwin, 2001, p.442) in attempts to eliminate the influence of politics in health policy. Clearly, political tensions involving issues of territory and power "*lie just below the surface*" despite semantics and language, which suggest otherwise: "*evidence becomes an instrument of politics rather than a substitute for it*" (Rodwin, 2001, p.442). Together with the clinical fraternity, policymakers rely on Newtonian models of thinking to bring about order and reducing uncertainty in the search for a robust and coherent evidence-base (Martin and Sturmberg, p107). Hunter (2003a) insists that inadequacies in the evidence base for health issues should not be used as an excuse for inaction. Importantly, complexity theorists understand that a system will never operate in equilibrium or in an idealised state; instead areas of tension and paradox should be accepted. In this context, a lack of evidence should not preclude action at some level, rather than moving into a period of apathy and stasis. Section 2.4.6 will consider how evidence is used in policy and practice.

2.4.6 The influence of evidence on policy and practice

Dumitrescu *et al.* (2006) argue that the contrasting perceptions, expectations and demands of the producers and the users of evidence reinforce the gap between research and policy. The evidence producers in the research world place importance on scientific rigour and probabilistic generalisability of findings whereas policy makers at the other end of the research/practice pathway are more interested in the relevance, specificity and fitness for use of evidence. Policy makers should have input into the process from conception of the question of interest, choice of methods, the type of evidence gathered, the process of analysis and interpretation of findings (Dumitrescu *et al.*, 2006).

Based on work by Legowski and Mckay conducted in Canada, Hunter (2003a) speculates that there are three main barriers to policy implementation in the UK: namely (i) fiscal constraints; (ii) a focus on health care rather than health promotion and public health and (iii) a propensity to fund narrow, short term, 'quick win' projects rather than long term up-stream strategies. Hunter (2003a) goes on further to suggest that the actual causes are more deeply rooted than that and are essentially a result of the inherent complexity of public health. The reasons, again, are threefold. First, Hunter describes the focus on the *"surface appeal"* of public health rather than on the real and wicked issues as a significant problem (2003a, p.12). Second, difficulties arise through the broad nature of public health and the idea that it is 'everyone's business', which leads to fragmentation and a lack of accountability (Littlejohns and Kelly, 2005). Finally, the obfuscation of health, by focussing on health care, contributes to disorder, uncertainty and 'messiness' in the policy implementation pathway. Through application of the complexity metaphor, Hunter recognises that these barriers will persist if practitioners and policy makers continue in their attempts to reduce, measure and quantify what is fundamentally a multi-faceted and complex phenomenon.

Several authors point to the troubling gap between policy makers and researchers as a limitation to evidence-based decision-making (Ham, Hunter and Robinson, 1995; Macintyre *et al.*, 2001; Nutley, Walter and Davies, 2002; Petticrew and Roberts, 2003). Through explorations of the research to policy pathway, Smith (2007) suggests that the cultural gap between researchers and policy makers cannot be bridged simply through the development of a common language and shared incentives as has been suggested by others. The

cultural differences are described as substantive rather than dialogical, therefore strategies aiming to bridge the divide should look at the whole system rather than just the superficial differences between the two cultures in terms of language and discourse.

In 1995, Ham, Hunter and Robinson, early proponents of evidence-based policy and practice, emphasised the need for a mechanism to translate research into policy. A 'hub and spoke' model (incorporating a central research focussed hub with satellite centres across the country) was endorsed for disseminating research outputs beyond the academic milieu thereby providing a channel to bridge the gap between research and policy. In this way research could infiltrate at all levels of policymaking, affecting local, regional and central government. A decade later and it is still suggested that the 'gap' between researchers and policy makers exists, some going so far as to say that it is more like a chasm (Davies, Nutley and Smith, 2000). Both researchers and policymakers operate within traditionally closed cultures although attempts are being made to encourage cross talk and collaboration.

It is acknowledged that a common dialogue is needed. Petticrew and Roberts (2003) believe there is a certain naivety amongst researchers about the nuances of the policy process, and the political, rationing, temporal and pragmatic drivers involved. Decision-making is based upon more than just evidence of effectiveness. Macintyre and associates (2001) developed a matrix of criteria used to evaluate policy recommendations as set out below (see table 2.8). It can be seen in their framework that evidence of what works and plausibility of that particular strategy are only two out of a plethora of factors to be taken into account in policy making.

Table 2.7 Criteria to evaluate policy recommendations (Macintyre et al., 2001, p.223)

Criteria
Supported by systematic empirical evidence
Supported by cogent argument
Scale of likely health benefit
Likelihood that the policy would bring benefits other than health benefits
Fit with existing or proposed government policy
Possibility that the policy may do harm
Ease of implementation
Cost of implementation

Nutley and Davies (2000) highlight the 'large gap between rhetoric and reality' in relation to evidence-based policy, which they attribute at least in part to the institutionalisation of the process of collecting evidence by Universities. Research is still not regularly used in practice, probably due to fragmented relations between researchers and practitioners working in very different cultural environments, with distinct objectives and priorities and divergent values (Davies, Nutley and Smith, 1999). Other factors may act as barriers to successful implementation of evidence into the policy process such as findings being inconclusive, difficult to interpret or of dubious value. To make evidence-based policy a reality there is a need to promote effective dissemination of research findings and a shift towards a culture that accepts and appraises new and non-traditional strands of evidence.

Several authors point to the disparity between the wealth of academic research outputs and the apparent dearth of empirical evidence available for policy making (Macintyre *et al.*, 2001; Nutley, 2003). Rather than bridging the gap between research and policy, with one straightforward arc, Nutley (2003, p.15) argues that "*multiple, demountable footbridges seem preferable to a few uni-directional motorways*". Moreover, the author encourages the research and policy areas to move closer towards one another to work in partnership so that bridges are unnecessary (Nutley, 2003). The complexity of the relationship between research and policy is not ignored by Nutley who acknowledges that "*the relationships between research, knowledge, policy and practice are always likely to remain loose, shifting and contingent*" (Nutley, 2003, p. 16) so, accordingly, partnership approaches to address the research-policy dichotomy should recognise and account for these complexities.

The central tenets of complexity theory are resonant with Nutley's conceptualisation of evidence-based decision-making. The system is open to influence by external as well as internal drivers, which interact in a state far from equilibrium. These commonalities will be discussed in further detail in the proceeding chapter: complexity and public health decision-making. A methodological critique of a selection of empirical studies regarding the utilisation of evidence in decision-making now follows.

2.4.7 Empirical studies of the research to policy process

Several models of the research to policy process have been put forward.

Given the scope of this review, the purpose is not to critique these schema comprehensively but to draw attention to the range and type of models used to articulate the research to policy process. Weiss (1979) proposed several models of research utilisation including: the engineering/problem solving model; the interactive model; the enlightenment model; the political model and the tactical model (cited in Nutley, 2003). Like rationalist models of decision-making, the engineering or problem solving model is based on positivistic assumptions ignoring context and visualising the process as a linear trajectory with tangible results. Few instances of research influencing policy making in this manner have been observed in practice (Elliott and Popay, 2000; Nutley, 2003).

In contrast, the interactive model, suggests that the impact of evidence on policy is more diffuse and involves interaction and understanding between the research and policy communities (Nutley, 2003; Petticrew *et al.*, 2004). The enlightenment or percolation metaphor views research utilisation as an evolving process that draws on a multiplicity of perspectives, values and theories. Research is used to 'enlighten' decision-makers about how issues are framed rather than concentrating on finding the single 'best' solution (Bowen and Zwi, 2005; Kemm, 2006). Kemm goes on to endorse the 'enlightenment' model, which requires researchers and policy makers to work in collaboration in an organic decision-making process. In this way policymakers help to frame the research questions and researchers take into account the intricacies and difficulties of policy making and the relations between competing drivers. Finally, the political model frames the process as a means of producing 'ammunition' (Nutley, 2003) to achieve political gain, while the tactical model comes into play when there is pressure for action and an explicit need for results in a certain area (Hanney *et al.* 2003). These models have been further developed and drawn on to guide contemporary empirical studies, a selection of which will now be debated:

A workshop conducted to examine perceptions of the evidence to policy process, showed that there was a dearth of evidence relating to effectiveness and cost-effectiveness of interventions for use in the policy process (Petticrew *et al.*, 2004). The study sampled a broad range of public health policy advisors including those from education and social welfare as well as mainstream health. The authors point out that there was little disagreement in the workshop given

the range of policy advisers recruited. It is possible that the consensus achieved was an artefact of the methods adopted, that is the use of a workshop for data collection. Perhaps in a one to one interview situation the participants may have been less guarded and a broader spectrum of responses could have been achieved. Petticrew *et al.* (2004) also draw attention to the need for researchers (the evidence producers) to understand the time and resource constraints under which policy advisors operate. One respondent talked about the use of 'fig-leaf' evidence to consolidate existing policy rather than to inform and guide new policy making. This corresponds to Davey-Smith, Ebrahim and Frankel's (2001) suggestions, in relation to the health inequality agenda, that policy might inform evidence rather than evidence informing policy.

A slightly earlier study by Elliott and Popay (2000) considered how the linear, interactive and dialogical models of the evidence utilisation related to local policy making in the NHS. The methodology involved the use of in-depth interviews and documentary analysis in a multi-case study approach. Analysis of the findings found that the interactive model was more reflective than the linear, problem solving model with respect to the contribution of research to policy. Moreover, the findings suggest that evidence was not the only driver of decision-making and factors such as resource constraints, experiential knowledge, limited timeframes and national governance were often more important influences. The authors go on to assert the importance of the in-direct effects of research, such as introducing different perspectives, to widening the debate and developing relationships between the research and policy communities. Again there is limited generalisability due to the qualitative approach adopted, but the flipside is that more meaningful and illuminating data could be gathered in relation to 'how' and 'why' questions.

An empirical study into ethical practice and decision-making demonstrated a number of important values relating to what was termed 'ideal' decision-making (Rogers, 2004, p.448). The qualitative study, which involved over thirty semi-structured interviews, found that the values of transparency, honesty, consensus, respect, equality and cost effectiveness figured alongside a need to make the process evidence-based. Generalisability of the findings may be limited as the study was conducted in Scotland where, since devolution, different political and economic factors are in operation. A further limitation of the study concerns the absence of excerpts from interview transcripts to

demonstrate and justify thematic findings. The next section will summarise the literature relating to evidence as a driver of decision-making.

2.4.8 Strengths and weaknesses of the existing knowledge base: evidence as a driver for decision-making

A number of recent empirical studies have considered the role of evidence in policy decision pathways (Elliott and Popay, 2000; Petticrew *et al.*, 2004; Rogers, 2004). More information is needed to ascertain whether of not the findings are transferable to other settings with different political, historical and cultural drivers and constraints. In some instances, findings are specific to time and place and do not translate out of context (Rychetnik *et al.*, 2002). In addition, different stakeholders produce evidence of varying quality, completeness and transferability depending on the financial and structural resources available. Evidence is usually gathered for simple interventions and from easy to reach populations (Rychetnik *et al.*, 2002) and few studies address complex, multi-factorial issues, which are socially and culturally embedded.

When considering the evidence relating to health inequalities Kelly *et al.* (2006, p.7) comment

> *...it is drawn from a diversity of disciplines using different methods, it is incomplete, and it is biased in various ways, including political and ideological bias. This does not mean it is unusable; it means we must devise ways of sorting out the disciplinary differences, of filling the gaps and of articulating the bias while valuing the diversity.*

The same is true in terms of the knowledge base relating to public health decision-making. Data have been collected using a range of methods (from surveys through to workshops and individual interviews) by researchers operating within disparate epistemological paradigms each with his or her particular assumptions, experiences and biases. It is clear that decision-making cannot take place in a sanitised and controlled environment using reductionist methods such as prescriptive checklists to eliminate all forms of bias. The reality is far more complex. Debate now moves on to review the use of GIS within public health and the capacity of GIS technologies to facilitate decision-making pathways.

2.5 GIS mapping and decision-making in public health

From a historical perspective John Snow was the first public health

practitioner to use mapping as a tool to question prevailing public policy in the 19th century. Similarly, Charles Booth's Inquiry (1886-1903) fostered the idea of overlaying socio-economic data onto a cartographic map of London to provide a factual description of the social landscape at the time and to demonstrate patterns of mortality in relation to poverty (Dorling *et al.*, 2000). Almost a century later, the information revolution has introduced to public health new tools for: i) gathering, storing and managing data; ii) analysing data and iii) visualising and presenting data to decision-makers (Heywood, Cornelius and Carver, 1998; Tim, 1995). Geographical information systems illustrate these three key applications of information technology within one system. GIS is an approach that crosses discipline boundaries in keeping with the central ethos of public health. The use of IT packages, not least GIS, requires specialist training to facilitate use and to prevent inappropriate application. GIS packages have applications in a variety of sectors including the military, retail, utility agencies, environmental protection, engineering, planning and transport (Monmonier, 1996) but remain underused in public health (Higgs and Gould, 2001).

Cox and Gifford (1997) comment on the issue of GIS and neutrality. Like other forms of data representation and statistical analysis, maps have the potential to 'lie' (Monmonier, 1996). Map depictions can look very different depending on classification, symbolisation and scale of the data (Cox and Gifford, 1997). In terms of methods of classification, whether equal interval, quantile or manual classification is used will affect the output map. Similarly, the number of classes used and the method of symbolisation (colour, hatching or dashed lines) will influence the visual impact and accessibility of the maps produced (Cox and Gifford, 1997). With respect to environmental lead data, issues such as changing ward boundaries and the introduction of a new census geography might affect data visualisation.

2.5.1 Uses of GIS and maps as evidence

The evolution of computer based mapping systems in the 1970s and 1980s has progressed the level of spatial analysis that can be undertaken when examining the distribution and spread of disease within a population. Dangermond (1990) summarises the main advantages of GIS, which includes data storage, retrieval, cartographic and presentation properties as shown in table 2.8. Some authors suggest that there are few limitations associated with

GIS technologies and any shortcomings are related to the data input into the system or user manipulation (Davis, 1996; Heuvelink, 1998).

Table 2.8: Advantages of GIS (adapted from Dangermond, 1990)

Advantage
Store and integrate spatially referenced data from multiple sources
Effective presentation of information in a form comprehensible to decision-makers who may not be able to rapidly distil knowledge from tabular data
Simulating the impact of policy changes (answering 'what if' questions)
Speedy data retrieval
Linkage of data to allow efficient access through an intuitive map based interface
Various efficient manipulation operations (measurement, overlay, transformation)
High quality cartography
Compact data storage
Data sharing between users
Back up copies
Quality checking

Myriad definitions exist for the term 'geographical information system' (GIS), some consider GIS as a tool (Chrisman, 1997) while others view GIS as a discipline in its own right (Wright, Goodchild and Proctor, 1997). The Chorley Report (1987) provides a broad definition of GIS:

> *a system for capturing, storing, checking, integrating, manipulating, analysing and displaying data which are spatially referenced to the earth. This is normally considered to involve a spatially referenced computer database and appropriate applications software...*[which is] *as important to spatial analysis as the invention of the microscope and the telescope were to science, the computer to economics and the printing press to information dissemination. It is the biggest step forward in the handling of geographic information since the invention of the map* (Department of Environment, 1987).

A working definition of GIS developed through discussion amongst GIS experts is proposed by Dueker and Kjerne (1989 cited by Chrisman, 1997, p.4):

> *a system of hardware, software, data, people, organisations, and institutional arrangements for collecting, storing, analysing and disseminating information about areas of the earth.*

Chrisman (1997) criticises this definition as bland but acknowledges that it covers all of the features and functions of GIS at a generic level. In the context of this study the definition is fitting as it emphasises the involvement of people and organisations at levels of data collection and dissemination. Boulos, Roudsari and Carson (2001) highlight the importance of GIS in facilitating an interdisciplinary approach to health related problems. This notion underlies the theoretical base of the study and the idea of interdisciplinary activity is inherent

during the stages of data collection, storage and analysis using GIS and then presentation and dissemination of the results to personnel involved in public health decision-making.

GIS approaches in public health were first employed in the fields of communicable and environmental disease but their applications are diversifying to examine the escalating problem of chronic disease. In an international context use of GIS in public health is increasing, particularly in the USA, due to the fall in the price of software and systems becoming more user-friendly and less time consuming to operate (http://www.who.int/csr/mapping/gisandphm/en/). The World Health Organisation (WHO) advocates the use of GIS as an interface between data and map, which enables information to be presented to decision-makers in a straightforward and effective manner (http://www.who.int/csr/mapping/gisandphm/en/). The WHO suggest a number of uses of GIS within the public health domain (see table 2.9 below).

Table 2.9: WHO suggested uses of GIS in public health (http://www.who.int/csr/mapping/gisandphm/en/)

Uses of GIS in Public Health
Examining the geographic distribution of disease
Analysing spatial and temporal patterns of disease
Mapping populations at risk
Stratifying risk factors
Assessing resource allocation
Planning and targeting interventions
Monitoring diseases and interventions over time

With some exceptions the language of GIS has filtered through into public health but the technology has not followed the same trajectory. A search of Medline yielded 203,579 articles with mapping as a keyword and only 165 of these referred to GIS. The remainder included uses referring to broader definitions of the term such as genetic/chromosomal mapping, forensic mapping and mapping of cognitive pathways. Cromley and McLafferty (2002, p.13) suggest that "*GIS maps can become metaphors for the social and environmental conditions that are 'contained' in geographic space*". Building on this premise, socio-economic and demographic data have been incorporated into the system to enable a broader understanding of the case issue.

A study by Cockings *et al.* (2004) recognises that barriers exist towards the mainstream use of GIS in health service settings. The study investigated

potential users' views on the usefulness of GIS compared with spatial point pattern analysis and traditional epidemiological techniques in investigating environmental health problems. The study is one of few conducted, which have addressed the value of GIS technologies within health services and research. Interestingly, three distinct approaches to environmental health problems were compared and the research consulted users from academia as well as environmental health practice.

Cockings and associates (2004) suggest that four key factors affect uptake of new methods such as GIS and point pattern analysis as alternative approaches to traditional epidemiology in public health practice. These include: (i) awareness; (ii) technical and financial resources; (iii) suitable organisational framework and strategies; (iv) level of understanding and perceptions of usefulness. In conclusion the authors call for a multi-disciplinary approach to environmental health issues and endorse the method which best fits the issue in question rather than a 'one shoe fits all solution' which nearly always involves the method that the user is most familiar or comfortable with. The study adopted a survey approach, which did not enable an opportunity for face to face contact and probing into responses. The benefit of such a strategy, however is that a greater sample size can be reached.

The capacity of GIS to integrate a range of different information relating to people and places makes them particularly useful in a public health context. Tunstall, Shaw and Dorling (2004) adopt a theoretical perspective to consider how the concept of place can be used in the study of public health. They argue that a broader definition of place is needed – a definition that encompasses the many factors that affect and are effected by place such as capital, social class, time, scale and migration. By understanding the full and complex notion of place they suggest that the relationship between place and health can be better appreciated. They argue that *"because place is in everything, in health, through space, through time, in genes, in class and how capital is expressed its omnipresence makes it all too often easy to ignore"* (Tunstall, Shaw and Dorling, 2004, p.8). The case study presented here, draws on Tunstall, Shaw and Dorling's holistic notion of place. GIS is used as a means to integrate a range of heterogeneous data and to present these data back to decision-makers to understand how GIS can be used at a strategic level.

The GIS visualisations represent new ways of making sense of existing

datasets. Stakeholders may have access to some of these data but time limitations, lack of expertise or equipment may preclude their involvement in analysis with GIS. Moreover, decision-makers do not necessarily have the opportunity to access these multiple, disparate data sets and to interrogate them using overlay analysis. There now follows a brief discussion of the case example within the case study, childhood lead exposure.

2.6 The case example within the case study: potential childhood lead exposure in Newcastle upon Tyne

A number of studies were conducted in the 1970s and 1980s when the issue of lead pollution was considered topical and there was a political consensus to address the problem of environmental contamination (Quinn, 1985; Fulton *et al.*, 1987; Thornton *et al.*, 1990). These studies used mainly positivist, quantitative approaches and tended to consider childhood lead exposure from an environmental, epidemiological or biomedical perspective, paying little attention to the social and political dimensions of the problem. In the past decade lead has been absent from the public health agenda but work has continued in the environmental sciences with a focus on soil contamination (Dilks, 2000, Hough *et al.*, 2004; Mellor, 2001; Vizard and Pless-Mulloli, 2003).

A recent report from the World Health Organisation called attention to the importance of lead exposure as a childhood health issue of global proportions (Valent *et al.*, 2004). When considering the outcome of 'mild mental retardation' (where IQ is between 50 and 70) lead was estimated to account for 4.4% of disability adjusted life years (DALYs)[3] in children aged between 0 and 4 years in Europe. At a national level, a press release from the Health Protection Agency (September, 2004) cited the effects of lead on children's cognitive development as a major area of concern, which called for further investigative work. Together these sources of evidence illustrate the re-emergence of lead as an important environmental and public health problem. For a more comprehensive appraisal of the literature relating to the issue of childhood lead exposure see appendix II of volume II.

Both the Black Report (Townsend and Davidson, 1982) and the Acheson

[3] The World Health Organisation define disability-adjusted life years (DALYs) as 'a comprehensive measure of health effects, calculated to include both years of life lived with disability and years of life lost (deaths).'

Report (1998) highlighted a pressing need to tackle health inequalities and recognised the importance of children in protecting the health of the nation. Since then strategies have focussed on improving the health of children and young mothers as it was accepted that in doing so the health of later generations should improve also. Despite the promise of a focus on children and a drive to reduce health inequalities through interagency working there is a general consensus amongst the public health community that these overarching philosophies fail to permeate through to action level. Socio-economic inequalities continue to persist and children lack a voice to be heard (Aynsley-Green, 2000).

The white paper of 2004 makes no explicit reference to the impact of the environment on health and focuses on individual healthy choice ignoring the fact that disadvantaged groups do not have the choice to live in green, healthy environments away from industry and major road networks. The issue of childhood lead exposure is complex with multiple dimensions and contingent relations. The problem is inextricably linked to persistent societal problems around inequity and inequality. Social, economic and political dimensions compound embedded environmental factors giving rise to an insidious but significant problem. The complexity of the issue of childhood lead exposure is dissected further in section 3.2.1.

UK public health policy has been silent on environmental issues despite recurring promises to foster interdisciplinary approaches to public health challenges. Environmental health issues remain the concern of specific agencies such as the Department of Environment, Fisheries and Rural Affairs (DEFRA) and the Environment Agency (EA) and there is little cross talk with public health bodies to facilitate a sustainable, interagency approach to environmental health hazards. Within DEFRA the evidence base is evolving and recent studies have considered emerging issues such as environmental justice (Walker *et al.*, 2003). More can be done, however, to consider the broader determinants of environmental health issues through multi-disciplinary collaboration. On a pan European scale the project presented here supports the EU environment and health strategy, which advocates a more 'integrated' approach to public health issues between the environment and health sectors at levels of monitoring, research and policy making (Garrity, 2003).

2.7 Conclusion

This chapter provides an overview of the multiple dimensions of public health decision-making. A number of inadequacies should be mentioned in relation to the existing literature base. It is clear that the reductionist and mechanistic decision-making processes of the past do not fit with the ethos of contemporary public health. Within public health, little progress has been made in terms of key issues: CHD is still the largest killer and health inequalities remain omnipresent in society (Graham and Kelly, 2004). By hanging on to traditional deterministic ways of examining problems and making decisions, these issues persist. There is an explicit need for change and new ways of understanding multi-dimensional and contextually embedded problems. Complexity offers an alternative route to the linear and often paternalistic decision-making paradigms of the 20th Century. The complexity approach does not deny the difficulties in dealing with persistent and multi-dimensional public health issues, instead the acceptance of disorder and uncertainty is encouraged.

Despite geographical system packages being available to public health agencies, the value of GIS evidence in decision-making is poorly understood. Few studies have been conducted to explore the usefulness of GIS data in the evidence base for policy making in the NHS or other agencies with a broad public health remit (with the exception of Cockings *et al.*, 2004; Dunn *et al.*, 2007; Higgs and Gould, 2001). The literature that does exist has adopted a quantitative approach, which does not access the underlying opinions and values of practitioners in the field. The study by Cockings *et al.* (2004) employed survey methods. While increasing the accessible sample size, such an approach does not allow face to face contact with respondents nor does it enable responses to be probed further.

Case study was deemed to be the most fitting methodology to reflect the multi-factorial elements both in decision-making and within GIS operations. Case study is an appropriate methodology when working within the complexity paradigm as it is flexible as well as reflexive and can reconcile both quantitative and qualitative techniques in a mixed method inquiry (Anderson *et al.*, 2005). The case example of childhood lead exposure presents a means of drawing together the key ingredients of the study: public health decision-making and the use of evidence in decision-making pathways. The case example is integral to

the case study in that it is a relevant multi-layered public health issue, which involves decision-making processes and is well suited to spatial exploration using GIS.

The literature review has served to draw together the key issues of interest: decision-making in public health and the use of evidence to ground or inform decisions. In addition, this chapter has sought to anchor and legitimise the use of the case study approach and complexity theory as the conceptual framework. To make sense of a multi-dimensional world complexity offers a useful framework for analysis and theoretical development in the public health domain. Complexity theory is not wholly new. Aspects of complexity have been referred to implicitly in relation to public health decision-making and will be examined further in the following chapter.

"Whatever the field the esprit of the post-modern era is complexity, at least in its largest sense: a combination of determinism and chance, a tolerance of heterogeneity and uncertainty and renewed attention placed on context and practicality"

(Materia and Baglio, 2005, p.534).

Chapter 3: Complexity and Public Health Decision-making

3.1 Introduction

The literature review pointed to the need to understand decision-making within a more appropriate framework to deal with the multi-faceted nature of contemporary public health problems. In this chapter the application of complexity theory within the public health context is considered. The potential benefits and limitations of applying a complexity approach to examine the notion of public health decision-making are discussed. A brief overview of complexity theory is laid out which highlights how complexity relates, confirms and conflicts with other philosophical and methodological approaches. Despite an omnipresent but often implicit recognition of the complexity of health issues, few researchers have developed complexity theory in relation to public health. There are of course exceptions namely: Gatrell (2005) whose work focuses on health geographies, Pearce and Merletti (2006) who apply complexity theory to epidemiological problems and Greenhalgh, Plesk, Wilson, Holt and Fraser (2001) who examine aspects of complexity within health care scenarios. Work by such authors will be appraised in an attempt to demonstrate the value of complexity theory in contemporary public health debate.

The central constructs of the paradigm will be introduced and illustrated with examples from public health policy and practice. The resonance between complexity and key elements of the study, such as collaboration, GIS and the case study design, will be explored. It is pertinent here to emphasise that the study does not attempt to advance the theory *per se*, rather the thesis considers the application of complexity in relation to the research question (is GIS mapping valued in the evidence base for public health decision-making?) The chapter will conclude with a discussion of the limitations of the complexity paradigm and will pave the way for the application of complexity theory in the ensuing chapters. Complexity theory is used as a navigation device in an empirical exploration of public health decision-making processes.

3.2 Significant concepts in complexity theory

Complexity theory goes beyond the dictionary definition of complex as "*consisting of several parts, composite; complicated*" (Oxford Current English Dictionary, 1990). It is a mistake to interpret complexity theory in the semantic sense only,

complex systems are defined by a number of shared properties which are alluded to in the range of definitions laid out below (see table 3.1). Perhaps due to the infancy of complexity as a science within its own right, ambiguity exists around a standard definition and those explanations that do exist vary quite significantly depending on the context in which they are applied. As Byrne (1998) asserts the goal of complexity is to provide a 'useful' way of understanding, without reducing whole systems to their component parts. Accordingly, precise and specific definitions may be limiting and counterproductive.

Table 3.1: A selected subset of definitions to demonstrate the different meanings attached to 'complexity' discourse

Discipline	Authors	Definition
Philosophy	Cilliers 1998, p.viii	"In a complex system...the interaction among constituents of the system, and the interaction between the system and its environment, are of such a nature that the system as a whole cannot be fully understood simply by analysing its component parts".
Chemistry	Whitesides and Ismagilov, 1999, p.89	"Complexity is a word rich with ambiguity and highly dependent on context".
Physics	Goldenfeld and Kadanoff, 1999, p.87	"...complexity means we have structure with variations".
General Science	Gallagher and Appenzeller, 1999, p.79	a complex system is "one whose properties are not fully explained by an understanding of its component parts".
Epidemiology	Pearce and Merletti 2006, p.516	"...self-organization, adaptation, upheavals at the edge of chaos, the unpredictability of effects of small changes in the initial conditions and the existence of simplicity at some levels while chaos exists at others – form the fundamental concepts of complexity".
Health Geography	Gatrell, 2005, p.2662	"In essence, a system displays complex behaviour when its elements interact in a non-linear fashion, such that it is impossible to predict the behaviour of the system as a whole from knowledge of the elements themselves".
Medicine	Plesk and Greenhalgh, 2001, p. 625	"A complex adaptive system is a collection of individual agents with freedom to act in ways that are not always totally predictable, and whose actions are interconnected so that one agent's actions changes the context for other agents".
Popular Science	Wahldrop, 1992 cited by Byrne 1998, p.16	"...there is a domain between deterministic order and randomness which is complex".
Ecology	Lovelock, 1991, p.188	Gaia theory: "present theory that sees the Earth as a system where the evolution of the organisms is tightly coupled to the evolution of their environment. Self-regulation of climate and chemical composition are emergent properties of the system".

The common themes suggested in these definitions are summarised for clarity in table 3.2. Again debate exists around these 'commonalities' and

indeed whether criteria can be set out to understand systems which are inherently complex and not amenable to simple reductionist and deterministic explanation (Arthur, 1999; Cilliers, 1998). This thesis has drawn upon the more succinct and accessible definitions provided by Waldrop (1992) and Geyer (2003). Waldrop (cited in Byrne, 1998, p.16) defines 'complexity' as *"the domain between linearly determined order and indeterminate chaos"*. Similarly, Geyer (2003) sees complexity as a bridge between states of order and disorder. While adopting the bridge metaphor in much of his work, Geyer is quick to point out that complexity should not be viewed as a dichotomy but rather a scale or spectrum (Cooper and Geyer, 2006). With regard to the study presented aspects of both order and disorder can be seen in public health decision-making processes: public health issues are rarely orderly and straightforward; evidence can be simple and monotechnic but equally chaotic and non-linear; discussion groups can reach consensus but more often than not disagreement and confusion prevail.

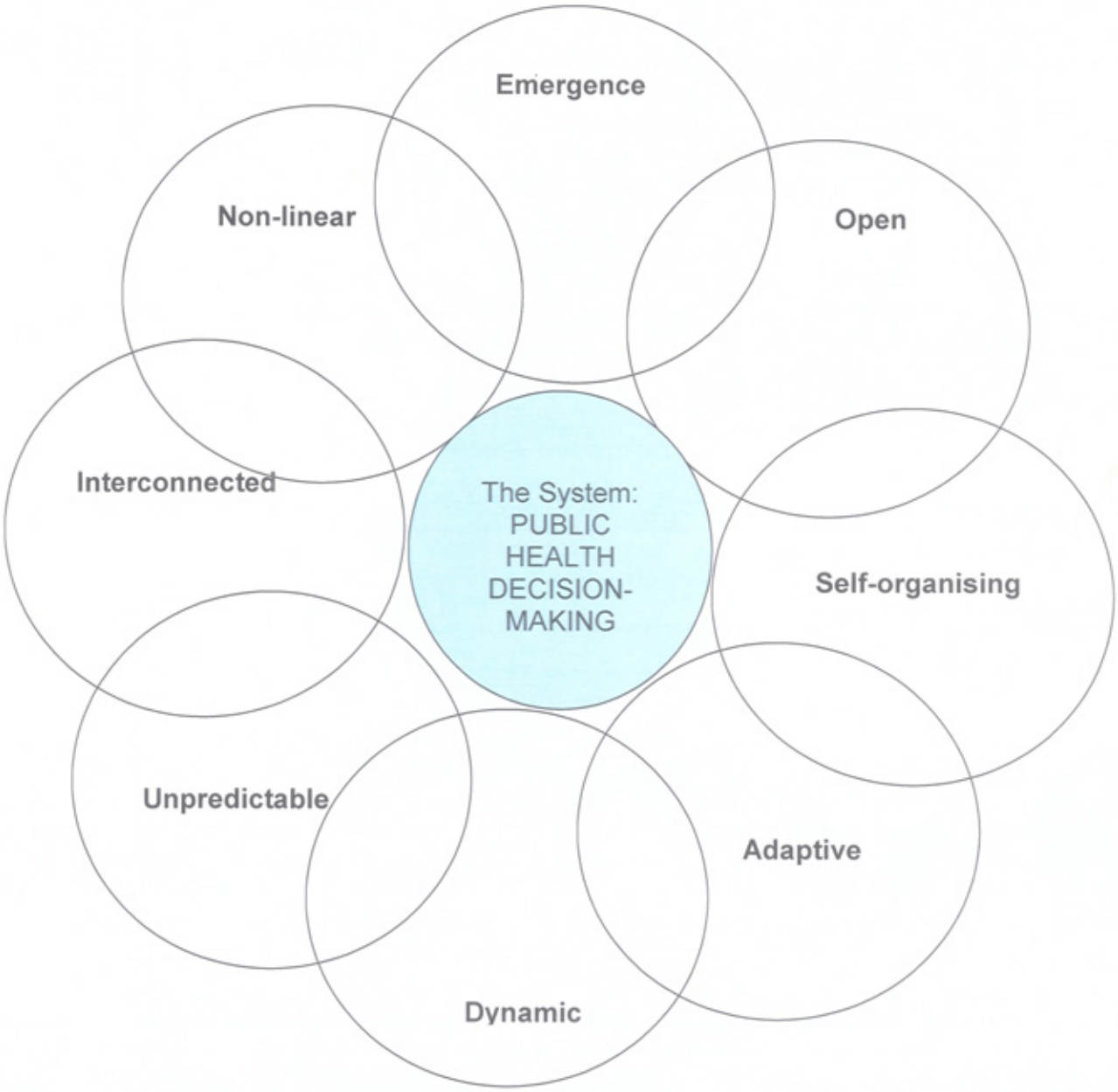
Table 3.2: Characteristics of complex adaptive systems (summarised from Cillers, 1998, p.4 and Geyer, 2003, p.237)

Characteristics of complex adaptive systems
Consist of a large number of elements which are necessary but not sufficient
The interaction is rich and varied, elements influence and are influenced by other elements
Elements are not cognizant of the whole system
Interactions are non-linear and short range
Systems are influenced by their environment
The systems do not operate in equilibrium
Complex adaptive systems have a history

Concepts from complexity science have been employed in a range of other disciplines from physics (Goldenfeld and Kandanoff, 1999), management (Schneider and Somers, 2006) and political science (Geyer, 2003) through to allied health (Newell, 2002) and clinical care (Wilson and Holt, 2001). Complexity theory is used in this study almost as a sounding board for getting to grips with the messy and difficult, interpreting areas of conflict and understanding the non-straightforward within an ever-changing environment. Complexity discourse draws on metaphor to explain what is difficult to articulate, by employing examples from the real world (Mikulecky, 2001). For instance, the notion that the whole is more than the sum of its component parts is captured

using the metaphor of an orchestra's performance being more than simply "*the addition of a group of brass, strings, woodwind and percussion, it is more analogous to an organism that has its own life*" (McQueen, 2000, p.96). The features or characteristics, which define the behaviour of a complex system (see figure 3.1) will now each be discussed in turn.

Figure 3.1: Characteristics of complex systems relevant to this study, the environment effects and is affected by all of the elements within the system



3.2.1 Emergence

Emergence is the defining property unique to complex systems that sets them apart from other systems. Emergence is the ability of the system to adapt to internal or external triggers, which can result in disproportionate effects to the

system as a whole; by way of illustration, a small change may be amplified to produce significant effects or behaviours at the systems level. For clarity, the system of interest, in this thesis, is public health decision-making.

To demonstrate how complex systems adapt their behaviour in response to their surroundings, Plesk and Greenhalgh (2001) employ the example of bacteria acquiring antibiotic resistance genes in response to overuse and misuse of antibacterial agents. In terms of the case example, childhood lead exposure, the children who are most at risk of exposure to environmental lead are those who are already at a disadvantage with respect to health. Children living in deprived areas are more likely to be exposed to lead contamination either through water delivered via lead pipes, playing on land with contemporary or historic heavy metal contamination, inhabiting houses with deteriorating leaded paint and living near major road networks[4].

Urry (2006) argues that the simplistic idea that the 'whole is more than the sum of its component parts' does not fully capture the distinctive property of emergence. Urry contends that emergence is the ability of the system to behave in ways unique from its component parts. Emergence is seen by Urry to be the 'spontaneous' development of collective properties, which are not reproducible in the individual components themselves. Here the example of the flavour of sugar is cited to demonstrate that taste is produced through the interactions of the constituent elements of carbon, hydrogen and oxygen, which on their own cannot simply replicate that flavour. Within the context of public health an obvious example is the omnipotent definition of health and well being as more than just simply the proper functioning of physiological systems. Social, spiritual and psychological dimensions affect well-being and it is the fine and delicate inter-relationships between these factors that bring about a change in health or disease status.

Similarly, contingent and relational elements are involved in the activities of public health practitioners. For instance, a practitioner working on smoking cessation strategies on the ground may only bring about marginal change but by co-ordinating a systems approach involving tobacco control policies, advertising legislation, workplace bans, sales regulations and education, change can be fostered at local, regional and national levels. Equally, effective

[4] Although lead is no longer in petrol, it is a persistent heavy metal with a long half life in soil.

public health policy around sexual health behaviours necessitates a whole systems approach involving government funded national campaigns, the provision of ring fenced budgets in the local NHS, improved access to services as well as risk reduction schemes, behavioural skills training and education programmes delivered locally in schools and to high risk groups (Kelly, 2004).

3.2.2 Attractors (internalised rules)

'Attractors' is a commonly used term within complexity debates and tends to refer to factors which influence the behaviour of complex adaptive systems. Byrne (1998) uses the simple example of a central heating system, where the attractors are defined as the upper and lower limits of the temperature range for the thermostat. When the ambient temperature goes below the lower attractor temperature the heating system switches on, whereas if air temperature increases above the upper attractor temperature the heating will automatically switch off. Byrne goes on to mention and define the existence of 'contingents' which in this example refer to other factors which may impact on the heating system's control of temperature such as windows or doors opening and closing, people entering or leaving the room, the existence of another source of heat, for example an open fire.

In the context of public health, an epidemic could be viewed as an attractor. Using the model of severe acute respiratory syndrome (SARS), where prevalence of the disease increases a series of responses are orchestrated. These responses might include containment of cases through isolation; therapy and treatment; epidemiological investigation to determine source, agent and pathway; population vaccination but also disease transmission. Plesk and Greenhalgh (2001) discuss the internalised (and often implicit) rules and regulations within a complex system. In public health the familiar doctrine of preventing ill health and promoting well being could be explained as one such rule. Equally, in ethics, the notions of beneficence and non-malevolence (Beauchamp and Childress, 2001) constitute an internalised law which can act as an attractor within the larger system.

3.2.3 Embedded systems

Complexity discourse suggests that multiple systems are in operation and are mutually interdependent. To understand one system it is necessary to

examine the other systems embedded within the whole and the network of communication pathways between sub-systems and the environment. In terms of an individual case of depression, diagnosis and subsequent treatment should take into account the patient's individual systems of social support, coping and behavioural strategies as well as the physiological pathways that give rise to the condition. At a population level, mental health treatment guidelines incorporate a broad based approach to treatment and management of the condition, which includes antidepressant medication supported with physical exercise and talking strategies such as cognitive behavioural therapy, counselling and problem-solving therapy (National Institute for Health and Clinical Excellence, 2004). There is a continuing awareness, driven in particular by the voluntary sector, of the need to understand stigmatised diseases using holistic models of thinking where the inter-relationships between social, physical and cultural aspects are emphasised. By using this whole systems approach, focussing on the inter-connections between subsystems, it might be possible to better align current systems of therapy and care.

An example from the strategy and policy domain involves the 2004 Department of Health White Paper, 'Choosing health: making healthy choices easier', which endorsed an approach to health where informed individual choice was supported by an effective and adaptive public health infrastructure. Critics of the white paper maintain that the key notion of 'provision of support' is merely a euphemism for nanny state authoritarianism, which brings with it the associated costs to civil liberties (Fitzgerald, 2005). It is naïve in the extreme to suggest that individuals could be enabled to make healthy choices in environments that are inherently unsupportive and healthy choices are prohibitively expensive, inaccessible or are simply unavailable. The political rhetoric is cogent but there is an explicit failure to deliver direction and the required funding to put into place these support systems at ground level. To enable population change, adaptation and change at each level of the system is required. Stacey (1996) discusses the idea of 'shadow systems' which can influence, in a positive or negative direction, the behaviour of systems embedded in the whole. Advocates of the complexity approach highlight the need for co-evolution (Fraser and Greenhalgh, 2001) and the harmonization of embedded systems.

3.2.4 Fuzzy boundaries

In closed and static systems, boundaries are well defined and rigidly adhered to. Drawing on the example of randomised controlled trials (RCT) of new drugs, boundaries are set to control every conceivable part of the system from double blinding clinicians and subjects, to the isolation of participants, strict monitoring of food and drink intake and rigid adherence to trial protocols. But as was demonstrated with the Parexcel phase I clinical trial of an immunomodulatory drug in March 2006, not all parts of the system are predictable and random occurrences in a closed and inflexible system can result in dire consequences, in this case multiple organ dysfunction in four participants (BBC, 2006). Perhaps if the system (the clinical trial environment in this instance) had been more adaptive and reflexive, clinicians could have reacted faster to the adverse events encountered, rather than rigidly adhering to the drug administration protocol. Obviously, strict and prescriptive protocols are essential in any type of RCT but there is also a need for clinicians to have the flexibility to draw on their instincts, experience and expertise when things go wrong.

Moving back to focus on this thesis, attempts have been made to define public health in order to draw up clear and coherent boundaries for the study but as Verweij and Dawson (2007, p.17) maintain it is near to impossible to pin down the ephemeral nature of public health and to avoid the need for "fuzzy edges" in any conceptualisation of the phenomenon.

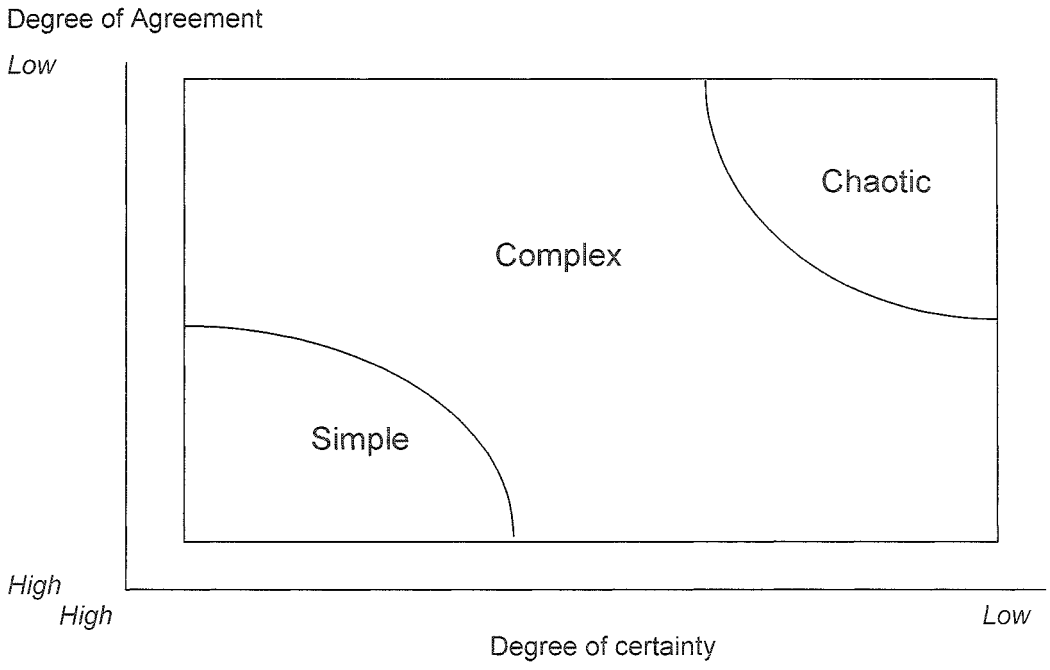
3.2.5 Inter-relationships: non-linearity and contingency

As Fraser and Greenhalgh (2001) acknowledge knowing how 'things' are related is as important as the knowledge of those 'things' themselves. It is around this premise that complexity is founded. The contingent relations between elements are at the crux of the matter – albeit the positive, the negative, the reinforcing, the negating, the reciprocal or the pluralistic inter-relationships. Within the public health domain the importance of contingent and reinforcing relations is illustrated in the example of breastfeeding behaviour in low-income groups. Interrelated factors such as limited education, absence of family experience, lack of familiarity with friends breastfeeding and a medicalisation of pregnancy and birth have been shown to affect breast feeding rates in a qualitative study in the North East of England (Bailey, Pain and

Aarvold, 2004). Determinants such as the cultural 'embeddedness' of bottle feeding practices are difficult to alter and are reinforced by the absence of examples of breastfeeding behaviour in family or friends. The array of interwoven and contingent variables come from both formal and informal sources and are difficult to interrupt using linear and mechanistic interventions alone.

Many authors adopt Stacey's agreement certainty matrix (see figure 3.2) to demonstrate the 'zone of complexity' within a system, where relations are neither simple and linear nor uncertain and chaotic (Stacey, 1996). Geyer (2003) refers to this complexity as the bridge between order and disorder whilst Langton (1990) describes such behaviours as operating at 'the edge of chaos' where systems function in a state which is neither ordered and straightforward nor chaotic and turbulent. In the context of the research presented here public health decision-making does not fit neatly into either a simple or chaotic model of understanding. There are simple, linear and predictive components such as the undisputed demands for evidence-based decisions but as Plesk and Greenhalgh (2001) contend, any system involving groups of individuals is associated with paradox, 'unknowables' and uncertainty.

Figure 3.2: The Stacey Diagram (Stacey, 1996, p.46)



Kelly, Speller and Meyrick (2004, p.7) describe how the Health Development Agency[5] (HDA) employed Stacey's certainty matrix as a "first stage decision-making model" to determine instances in which to (i) use evidence; (ii) consider policy changes and (iii) to develop practice. They conclude that change can only be implemented when levels of both agreement and certainty are high (bottom left portion of the matrix). In conditions where either agreement or certainty is low, change should be proceeded through creative pathways of experimentation and innovation.

Pearce and Merletti (2006) suggest that complexity theory enables researchers to ask new, unusual and non-linear questions, which would be difficult to address when employing a different framework, for example the positivist paradigm. Traditional positivist or reductionist approaches, while remaining entrenched in scientific culture, are criticised for over-simplifying the complex and for restraining the flow of information and knowledge between disciplines through micro-specialisation and the creation of "*sub-sub-subdisciplines*" (Gallagher and Appenzeller, 1999, p.79).

3.2.6 Paradox

Complexity attempts to make sense of competing forces, which can exert influence in political, professional and even biological and environmental guises. In public health, Rose (1985) drew attention to the 'prevention paradox', which refers to the idea that a public health initiative to benefit a population does not necessarily confer benefit to every individual. Examples include immunisation programmes and enforcing the use of seat belts in cars. In terms of the case example in this study, a screening strategy to test the blood lead levels of school children would not be in the best interest of the individual child but at the population level it could benefit research into the environmental exposure and uptake of lead.

Areas of paradox, conflict and uncertainty are inherent in the public health agenda. Issues such as the smoking ban illustrate the explicit tensions associated with protecting the public whilst not infringing on individual rights. The same conflict and debates between agency and structure resonate in the

[5] "The HDA was a special health authority established in 2000 to develop the evidence base to improve health and reduce inequalities...The functions of the HDA were transferred to the National Institute for Health and Clinical Excellence (NICE) on 1st April 2005" (http://www.nice.org.uk/page.aspx?o=abouthda)

case of 'Typhoid Mary'. Mary Mallon was an asymptomatic carrier of the typhoid pathogen, who worked as a cook in New York in the early 1900s (Chan and Reidpath, 2003). When identified as a carrier of *Salmonella* typhi during a sanitation investigation, Mary was incarcerated in an infectious disease hospital for three years (Carter, 1997). Upon release she was required not to work in a food handling role but her situation as a poor, female immigrant with limited skills meant that she was unable to earn a decent enough living to comply with those constraints (Chan and Reidpath, 2003). She returned to work as a cook under another name but was reincarcerated after an outbreak in 1915 until her death 23 years later (Carter, 1997). Here the tensions between individual agency and structural constraints aimed at protecting population health are well illustrated.

3.3 The ontological and epistemological basis of complexity

3.3.1 Complexity: an anti-positivist ontology

Geyer (2003) acknowledges the general rules underpinning the positivist approach, which he refers to as the paradigm of order: causality; reductionism (the whole equals the sum of its parts); predictability (past behaviours defines and predicts future outcomes) and determinism (orderly paths with rational beginnings and ends). While the reductionist approach might be useful when considering a single case as in clinical medicine (Byrne, 1998) public health is much more than the sum of its constituent parts.

Complex adaptive systems share a number of characteristics, rather than rules of behaviour, which were described in section 3.2 and include emergence, attractor properties and dynamic inter-relationships within open systems. This study is not attempting to advance complexity theory in the technical sense. Instead the paradigm is being borrowed and applied in the context of public health, in an empirical investigation of decision-making practices. It is possible however that lessons learnt from the application of complexity theory may contribute to the development of new and more fitting theoretical paradigms in the public health domain. This thesis is concerned with public health practice hence philosophical debates are discussed only briefly to provide context and a foundation for debate.

Byrne (1998) argues that complexity fits with the modernist programme although it is undisputed that complexity theory is not in keeping with the

positivist suppositions of hypothesis building, reductionism, quantification of component parts, and replication of findings in closed systems. Instead the focus is on relations and inter-connections within systems and their environment. Cillers (1998), an eminent exponent of complexity theory, proposes that complexity shares ontological roots with postmodernism. Rather than striving to obtain a universal knowledge, which is an exact reflection of reality, postmodernists argue that there is no single truth and understandings are organic, constructed and shaped by experience, culture, tradition and circumstance (Drolet, 2004). Similarly, within complex adaptive systems, interactions are context specific and dynamic. There are, however, significant problems with Cillier's assertions, principally based on Lyotard's conceptualisation of postmodernism (Drolet, 2004), there is no such thing as generality, knowledge is relative, socially constructed and a multiplicity of micro-narratives are equally valid. Realist accounts provide more fitting explanations of the ontological and epistemological underpinnings of complexity theory and will be discussed in the following section.

3.3.2 Realist epistemology

Complexity science is acknowledged as an embryonic discipline but one that offers plentiful opportunities to apply theory and hence augment the development of the conceptual base for complexity. Much of complexity theory has emerged from the natural sciences, in particular mathematics and physics. In line with the modernist tradition, systems theory attempts to seek 'general laws of objectivied processes' (Outhwaite, 1987, p.87). Complexity draws on the precepts of general systems theory (developed in part by von Bertalanffy, 1968) which endorsed the notion of self-regulation and homeostasis in open systems (Stacey, 2007) and viewed systems as holistic and organic entities. Later Beer (1979) was instrumental in the cybernetic systems movement where the central concept is the importance of the environment and the system's ability to self-regulate (Stacey, 2007).

As a discipline complexity is not wholly new. The notions of open systems, social context and historical contingency are resonant with Bhaskar's critical realism. Bhaskar (1989) accepts both the objective and subjective/transitive forms of knowledge by employing critical reasoning to delineate the relationships between what is known and what exists but is

unknown. This structuring of ontology into real, actual and empirical dimensions is referred to as 'stratified emergence' (Irwin, 2007).

Realist accounts accept that knowledge is "*always provisional and open to challenge*" (Parker, 1998, p.3). According to Byrne (1998):

> *"The events which happen in the world are actual. Those things which we experience are empirical. The real may not become actual because the causal mechanisms are complex and contingent and the effects may be blocked. The actual may not become empirical because it is not necessarily observed.*

By drawing on the example of tuberculosis in Tyneside in the 1930s, Byrne effectively captures the essence of realism. He explains that exposure to the pathogen, although necessary, was not alone sufficient to cause the disease and three other risk factors were causally associated with the aetiology of tuberculosis. The interactions between poor housing, malnutrition and Irish nationality (due to lower exposure in previous generations) were *"complex and contingent"* (Byrne, 1998, p.39). Moreover, mediating factors such as good diet and adequate living conditions could block expression of the disease. This example serves to illustrate how reality may not be immediately discernible by the senses (Reed and Harvey, 1992) due to the complex inter-relationships of the whole system.

Reed and Harvey (1992) argue that the complexity programme has emerged at the crossroads between modernist and postmodernist thinking. Realism embodies the rationality endorsed by modernists while retaining a flexible and adaptive stance. Similarly, realist discourse takes account of context and a multiplicity of narratives without succumbing to irrationalism:

> *...for the critical realist, the proper goal of science lies not in prediction, but in the theoretical identification, typing and cataloguing of natural entities, their causal powers and generative mechanisms*

Habermas' approach (cited in Outhwaite, 1987) criticised positivism for failure to allow for self-reflection but rather than dismiss the successes of the Enlightenment, Habermas situates rationality in terms of interpersonal and linguistic communciation rather than sensory experience alone in his theory of communicative action:

> *'The construction of a world of objects or possible experience' involves 'a systematic interplay of sensuous reception, action and linguistic representation'* (Outhwaite, 1987).

In terms of the study presented here, GIS mapping provides an opportunity to enable *'sensuous reception'* and *'linguistic representation'* through which the

audience can engage with public health issues in a straightforward and accessible manner. Outhwaite captures the importance of participant interaction and the need to understand the system from the perspective of those involved. He summarises communicative action as the study of society as both the study of systems of actions/processes by the observer and the study of life worlds, from the perspective of the participant or member:

> *...it seems that instrumental and strategic action are coordinated with social scientific perspectives such as system theory, and communicative action with those orientated in the life-world – the perspectives of observer and virtual participant* (Outhwaite, 1987).

Habermas recognises the fallibility of this depiction, which drawing on Bhaskar's work makes three broad assumptions *'(i) the autonomy of actors, (ii) the independence of culture, and (iii) the transparency of communication'* (Outhwaite, 1987). Equally, a systems approach has weaknesses when viewed in isolation, not least its inability to frame a phenomena in terms of the life-world's of those involved.

Inherently opposed to technocratic control and political manipulation Habermas' critical theory is a *"fusion of system and life-world perspectives"*. These ideas, like Bhaskar's, draw upon our innate capacity for reason and critique and have potential to work towards emancipation and a more just, liberal version of society. There is potential to apply critical theory in the field of public health to question prevailing discourse and to further understanding of action and processes using critical reasoning.

3.3.3 Complexity theory versus chaos theory

To avoid ambiguity it is important now to discuss the distinction between chaos and complexity. Goldenfeld and Kadanoff (1999, p.87) define chaos as:

> *the sensitive dependence of a final result upon the initial conditions that bring it about. In a chaotic world, it is hard to predict which variation will arise in a given place and time. Indeed, errors and uncertainties often grow exponentially with time.*

The important concept to take from the above quote is the distinction that complex adaptive systems (unlike chaotic systems) possess elements of order rather than just chaos alone. When discussing chaos theory many authors cite the Butterfly Effect, which is ubiquitous in popularist scientific literature and describes the example of a butterfly flapping its wings in London, which

produces a ripple effect resulting in an earthquake in San Francisco. Stacey (1996) offers the example of weather systems, which are mediated by non linear feedback from a number of inter-related variables including pressure, temperature, humidity and wind speed. Accordingly a small change in one of those contingent variables can result in a large impact on the system overall.

The idea of a small change giving rise to a large effect flies in the face of positivist tradition and is very in keeping with public health thinking in the 21st Century. A pertinent example involves the emergence of the MRSA epidemic due to poor hand washing regimes within hospitals. The resistant mutants emerged through overuse and misuse of antibiotics but it was a relatively small behavioural change (poor compliance with hand washing regimes) that led to the prolific spread of disease.

Due to the absence of a consensus definition of complexity the significant features of complex adaptive systems seem to be agreed across disciplines. Even physicists, who work in an environment where positivism is taken as the only way of knowing and experimental models as the archetypal research paradigm, are beginning to look outside of their silos to embrace new ways of thinking such as complexity (Goldenfeld and Kandanoff, 1999). In the case of complexity science, physicists and other quantitative researchers need to change their mindset to appreciate that there are no laws as such, rather there are 'lessons' to be learnt to advance understanding (Goldenfeld and Kadanoff, 1999). The authors go on to posit that "*maybe physics studies will become more like human experience where a multiplicity of permutations exist in dynamic interaction*" (Goldenfeld and Kadanoff, 1999, p.79). It is possible that a paradigm shift (Kuhn, 1996) may be on the horizon, giving rise to ideal circumstances to invoke change and innovation throughout the disciplines.

3.4 Complexity and public health

The notion of complexity in health related disciplines is not new. Ideas have been bandied about for some time in contemporary health debate, often using language akin to complexity discourse but without engaging with the theory of complexity itself. Insight can be gleaned and knowledge and theory developed by examining the use of complexity in other disciplines.

In terms of health and disease, Wilson and Holt (2001) are quick to recognise that few health conditions have a singular 'cause' or indeed a simple

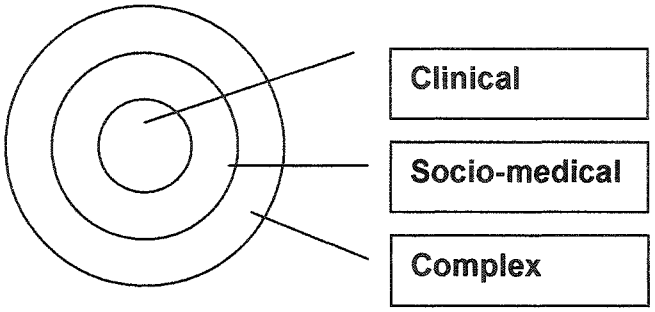
'cure'. Again Byrne (1998) draws on the example of tuberculosis to demonstrate the complex nature of health issues. Using a nested, or embedded, systems approach, Byrne reminds us that the aetiology of tuberculosis is not simply a linear pathway linking infection by *Mycobacterium tuberculosis* with manifestation of the disease, tuberculosis. Many other inter-dependent factors come into play at the individual, community and societal/structural levels. Clearly, tuberculosis is a disease with explicit social, cultural and economic dimensions. Contemporary risk factors include living in overcrowded dwellings or being homeless; immunocompromise (for example co-infection with HIV); and genetic susceptibility. Essentially tuberculosis is a disease whose effects and incidence are compounded by poverty.

The resurgence of tuberculosis in an antimicrobial resistant guise is an emerging public health challenge in the 21st Century and one that requires non-linear strategies to deal with the inter-related social, political and clinical aspects of the problem. While attempts to discover new antibiotics are to be welcomed, public health strategies must also look at ways to make cheaper, accessible and improved anti-retro viral therapies for high risk individuals with HIV and more importantly strategies should target the wider determinants of homelessness and poverty at the societal level.

Current public health issues are thorny and difficult. Factors of causality, if identifiable, are often deeply interwoven and culturally embedded in society. As discussed in chapter 2, there is a multiplicity of definitions of health, encompassing biomedical and reductionist models characterised by the 'absence of disease' to functionalist appraisals where health is defined by the ability to do a job and holistic definitions which incorporate spirituality and emotional well being. There seems to be consensus that the WHO definition is fairly comprehensive and as such has been adopted by many public health practitioners. Debate will now move on to consider how a complexity theorist might define health.

Figure 3.3: Byrnes visualization of tuberculosis using a nested systems approach

Clinical	Socio-medical	Complexity
Bacterial aetiology	Transmission augmented by over-crowding and immunocompromise	Disease of society
Antibiotics and Immunisation	Social housing policy HIV therapy/prevention	Eradicate poverty



O'Neall and Brownson (2004) discuss the complexity of the public health field, in a purely descriptive sense making reference to:

- the diversity of population levels served (national, local, community);
- emerging health threats (infectious agents, chronic disease, climate change, biochemical warfare);
- technological advances (new tools resulting in training demands);
- demographic changes;
- political pressures (priority setting, rationing).

Although this description is dialogical rather than theoretical, the conceptual links are implicit and linkages with complex adaptive systems can be made. For example, population levels could be seen as nested systems in an open and adaptive environment with multiple and reciprocal relationships between. Likewise the inter-relatedness of emerging health threats is alluded to.

Current public health literature points to the over dependence on the mechanical model of health and ill health and Newton's clockwork universe (Plesk and Greenhalgh, 2001). The randomised control trial is still referred to as the gold standard in medicine, for measuring the magnitude of an effect, (Gatrell, 2005) and reductionist approaches are deeply embedded in health research. Accordingly, public health initiatives have, in the past, reflected this positivist stance, characterised by a closed system approach where researchers are regarded as passive observers of facts (Bhaskar, 1989, p.51).

Despite the dominance of positivism, contemporary public health methodologies are trying to move away from traditional, reductionist paradigms to embrace multiple, complementary perspectives thereby accepting the complex non-linearity of population health problems. While recognising the fallibility of positivist research strategies, it is overly simplistic to regard positivism and interpretivism as a dichotomy. Rather a more fitting analogy is a spectrum which takes account of the nuances of other epistemologies. Pluralistic approaches are becoming more popular in research (Naidoo and Orme, 1998), whereby diverse qualitative or quantitative approaches are regarded as equally valid and methodology is guided by the research question rather than a one size fits all, gold standard approach.

Government initiatives have presented overly simplistic strategies to deal with health problems, which are inherently complex and multidimensional, for example the use of Body Mass Index (BMI) tests in schools to tackle the obesity epidemic. These strategies often appear near sighted and rarely consider the wider social, economic and political determinants, or indeed the determinants of the determinants (Mindell *et al.*, 2004). Health is clearly a highly complex phenomenon; it is everything and nothing so how can a path be cut through it? The complexity paradigm does not provide a clear-cut solution to this question but it does make it easier to grasp and understand by making explicit the intricate relations between factors and sub-factors and the influential minutiae that contribute to health's complicated dynamics. By recognising and acknowledging - rather than ignoring - the complexity of public health issues it might be easier to make headway with novel, innovative and workable solutions. Applying the complexity model could provide a useable template for the public health practitioner to negotiate a way forward that accommodates the maximum number of disparate voices.

3.5 Complexity in decision-making

Decisions are not simply made in a straightforward, linear manner incorporating the best evidence available. Due to the necessary human component, decision-making is messy, disordered and unpredictable. Each actor comes to the process with their own set of priorities, concerns and hopes driven by

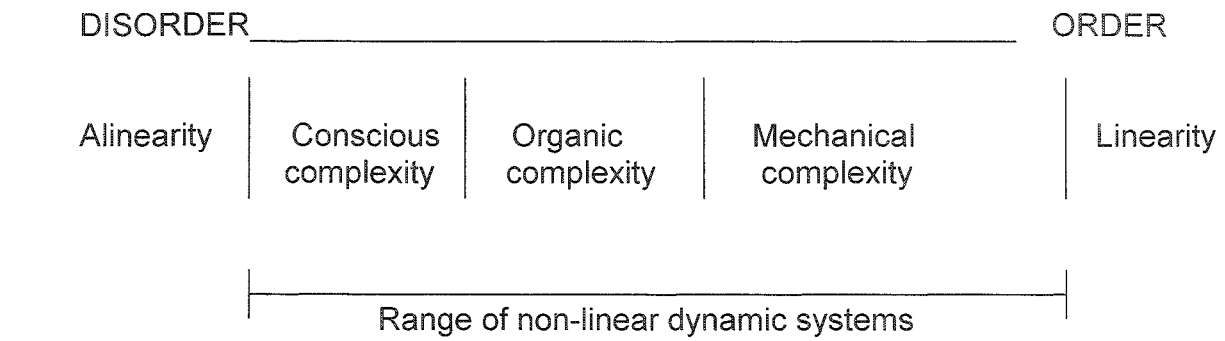
their underlying core values and belief systems. Despite aiming to be an open and judicious process, decision-making is often politically motivated and may not always equally reflect the requirements of all stakeholders involved.

Decision-making involves a network of inter-related variables including the opinions, experiences, prejudices, values, and tacit knowledge of all those involved. Non-anthropogenic factors influences include: current circumstance, political climate as well as the social and cultural environment. Empirical evidence is sometimes the least important element in decision-making (Pawson, 2006) despite being, arguably, the most linear and ordered quotient. But then what counts as the best or most relevant evidence for the question of interest is a contested issue and may vary depending on stakeholder perceptions.

It can be seen that the decision-making process is not easily reduced to its component parts and cannot be properly understood by thinking about each variable in isolation as per the engineering model, resonant with biomedical practice. Complexity theory suggests that it is the dynamic between variables that determines how the system as a whole behaves; in other words how decisions are made and which variables come into the frame, including but not restricted to evidence. Geyer (2003) uses a spectrum diagram to articulate and visualize complexity in policy making processes (see figure 4a). Geyer's approach is drawn upon to visualise the elements of order and disorder within this study (refer to figure 4b). The schemas have been produced to illustrate the layers of order, disorder and complexity in research, evidence-based decision-making and specifically public health decision-making.

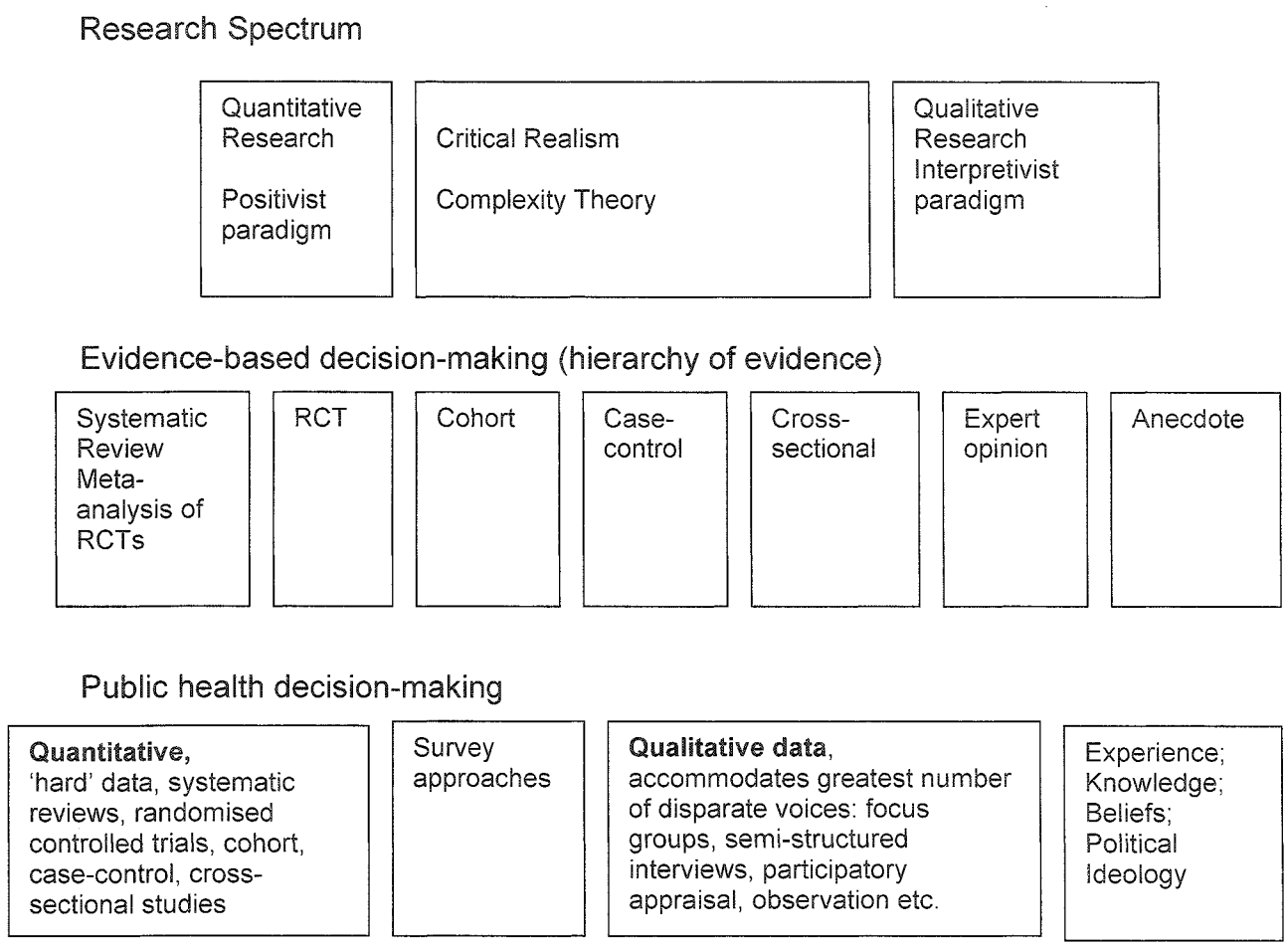
So far in this chapter, evidence has been viewed as the logical, reasoned and ordered component of decision-making systems but in actuality, evidence can be ephemeral or intangible in nature. The enlightenment model of decision-making is in keeping with the complexity world view, in that policy making is not inherently a linear process. Decision-making is affected by unpredictable elements (Hammersley, 2000) and should thus be understood as a dynamic process, which is responsive to the needs of all stakeholders (Fraser and Greenhalgh, 2001). Instead of adopting prescriptive checklist approaches, Fraser and Greenhalgh (2001) suggest that decision-making pathways should move towards open and flexible frameworks, which are enhanced by transparency and probity.

Figure 3.4a: Examples of complex adaptive systems applying the spectrum of order and disorder as devised by Geyer (2003).



Physical Phenomena				
Quantum mechanics Relativity theory		Species evolution plant & animal interaction	Fluid dynamics; weather patterns	Gravity; motion in a vacuum
Social Phenomena				
Severe physical & brain disorders; dreams; the unconscious	Norms/ values; language; narrative; interpretation	Group dynamics; institutional processes; the media	Crowd dynamics; electoral outcomes; economic laws	Basic physiological functions Life/death
European Union Phenomena				
EU long term development	European citizenship; policy implement-ation	Member state interaction; EU institutional interaction	Voting outcomes in the various institutions	Core short-term framework
International System Phenomena				
Long term development; the next world system	Nationalism; internationalism (human rights)	State & non-state actor interaction; institutional interaction	Voting outcomes in various international institutions	Basic framework and power relationships

Figure 3.4b: The spectrum of order and disorder with respect to this study (using Geyer's approach)



3.6 This study and complexity

As Cilliers (1998) explains complexity theory cannot be relied on to describe and explain a complex adaptive system in its entirety. Moreover, complexity provides a 'framework' (Cilliers, 1998, p. 141) to be drawn upon and expanded by the subject specialist. In fairness 'public health' and 'decision-making' could both individually be viewed as complex adaptive systems and GIS as a tool to examine the elements of order and disorder whilst accepting the complexity of both phenomena. Here public health decision-making will be considered as a complex adaptive system in itself.

The multiple dimensions of public health decision-making are demonstrated through the application of contemporary definitions of public health. Public health is affected by a cacophony of interconnected determinants: the social, political, economic, environmental as well as the physiological or biomedical. Since public health is determined by such a vast

array of extraneous variables it follows that it should be thought of as an open system. Equally, the use of linear and reductionist approaches to explore or examine public health issues can result in misunderstanding and de-contextualisation.

At a higher level, the social milieu for making public health decisions is neither straightforward nor constant. Unpredictable and competing variables interact to create an unstable, messy and disordered environment. Despite the best intentions of public health practitioners, decision-making is based, more often that not, on factors other than the best evidence available. Variables such as personal experience, tacit knowledge, values, beliefs, common sense, political inclinations and personal preferences can overshadow the judicious process of decision-making. Pawson (2006) suggests that realist synthesis can offer an alternative approach. Realist synthesis is an iterative and reflexive process, which evolves, adapts and develops on the basis of the decisions undertaken by the evidence review team (Pawson, 2006).

Drawing on the overarching belief that public health is complex and decision-making is complex, GIS as a tool is complex and the data sources for mapping are complex (incomplete, out of date, inaccurate), therefore in the process of bringing together each of these dimensions synergistically, it follows that the case study represents a complex endeavour. However, as previously discussed, just because something is complicated and multifaceted does not necessarily mean that it is a complex system. Using the criteria laid out in table 3.2, it is possible, however, to illustrate that the phenomenon of interest (public health decision-making) demonstrates characteristics of a complex adaptive system. These suggestions and deliberations are summarised in table 3.4.

Table 3.4: Cilliers (1998) characteristics of complexity are adapted to understand elements of complexity in the context of public health decision-making.

Complexity	Public health decision-making
Large number of elements	The array of elements involved in decision-making processes: decision-makers views (and hidden agendas), organisational perspectives, 'evidence', government rhetoric, public opinion, political will, time, money, resources etc.
Dynamic interaction	Decision-makers are constantly engaged in information exchange locally, nationally and internationally. Interactions occur with data and information, between individuals and within and between organisations.
Rich interaction	These interactions are rich and varied, positive and negative and constantly evolving.
Non-linearity	Non-linearity and asymmetry exist within a decision-making body. Power relations impact on the value of information to different individuals within the group. .
Short range interaction	Decisions within an organisation are mediated locally but may have effects outwith this initial environment.
Feedback loops exist	Feedback loops ensure that the 'picture' is constantly changing depending on time, space and place. Decisions are reflexive and changes on a national or international platform mean that iterations are required on a regular basis.
Open systems	Due to the wide reaching effects of public health interventions decisions can impact on and are affected by other systems such as the environment, education and economic sectors. The effects of public health decisions should not be viewed in isolation.
State of non equilibrium	Decision-making can rarely be viewed as a symmetrical or static process. Changes in the economy of knowledge and power are ever present and the optimum decision may vary according to changing environment, resources or public opinion.
History	Historical events and processes affect public health decision-making and shape how conclusions are reached. For example, the structuralist, consensus and pluralist models of decision-making have all contributed in some way to current methods of best practice.
Individual parts do not comprehend the whole system	Unfortunately the consequences of any one actor's actions cannot be fully understood and predicted at ground level. For example, using a hypothetical scenario, the best intentions of a PCT to promote and support allotments and local food initiatives may unwittingly expose the population to the effects of land contaminants.

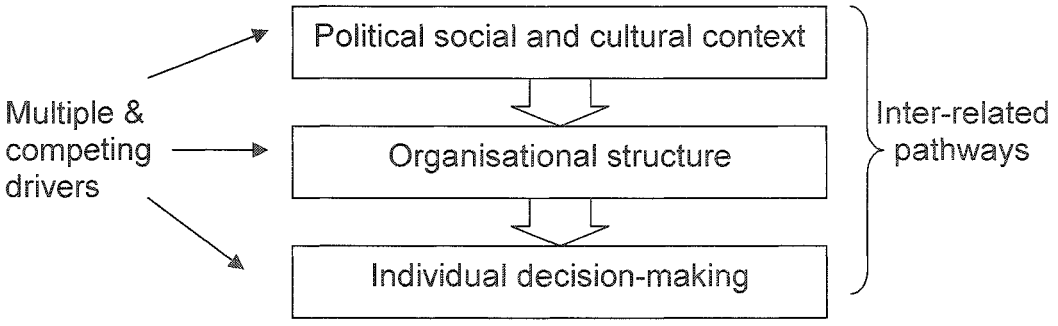
In terms of understanding the complexity of the case study a critique of the complex aspects of decision-making is outlined. First, decisions can be

based on simple or straightforward processes normally involving quantitative evidence taken to be the best available (engineering model of policy making). On another level, decisions can often take into account more unpredictable variables or unmeasureables such as political climate, opinion, moral and ethical codes (Sanderson, 2006), historical events (Pearce and Merletti, 2006) and power plays. Geyer (2003) describes the two as elements of order and disorder and views complexity as a bridge to make sense of the two. Clearly, any process involving human input can be described as unpredictable and the level of order and disorder in decision-making processes tends to be mediated by factors which include amongst others: group dynamics, engagement with sources of evidence, time and resource constraints. Clearly, there are implications for public health practitioners in terms of training, capacity building and education which will be taken up in greater depth in chapter 8.

The ability to self-organise is another important characteristic of complex systems. Interactions tend to be dynamic rather than static. In a complex adaptive system a change in one component leads to a non-linear change (an amplification or reduction) in the system as a whole. An example of the adaptive nature of public health decision-making can be observed in relation to the smoking ban which was first introduced as a partial ban before being upped to a total ban as public health practitioners were able to demonstrate that anything less might actually contribute to the inequality divide (Woodall *et al.*, 2005). In the context of this thesis, adaptive behaviour is likely to be seen in the relationships between decision-makers themselves and also with sources of evidence.

Complexity theory offers an alternative to current models of thinking and best practice with respect to public health decision-making (see figure 3.5 below).

Figure 3.5: Layers of complexity in public health decision-making (produced based on Wilson and Holt's (2001) ideas on factors affecting organisations).



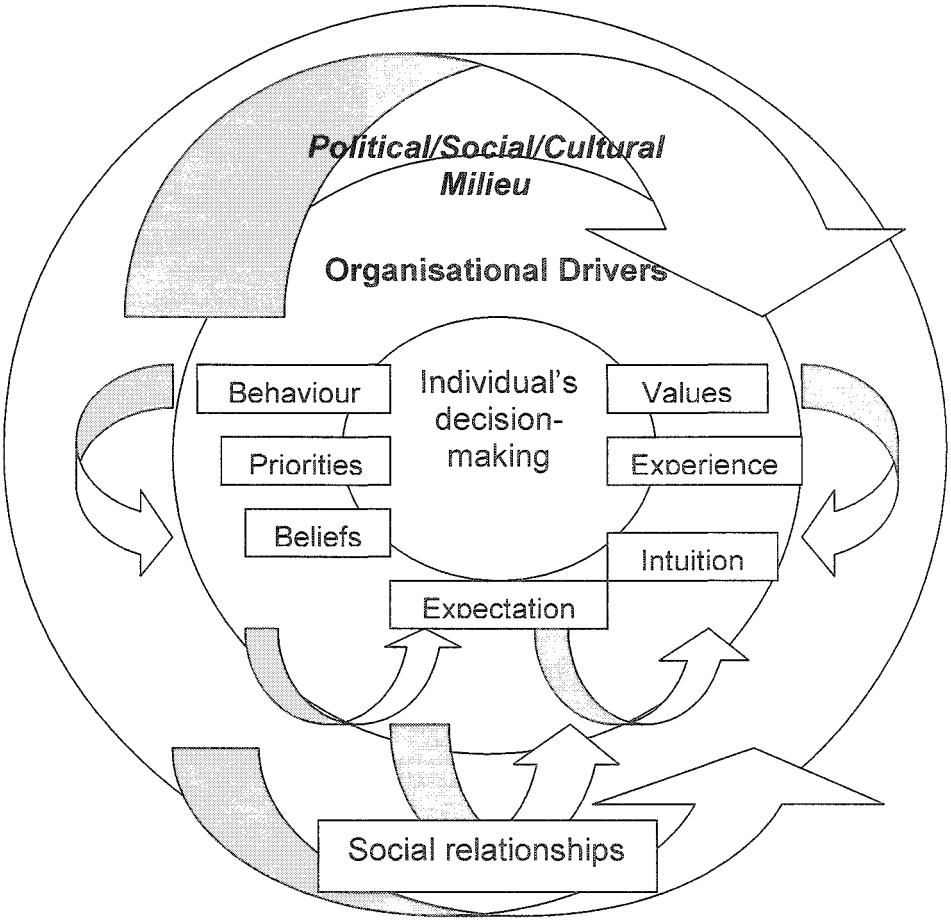
The systems are interconnected by multiple, intricate pathways, some subtle, some overt, some salient, some minor. It is therefore misleading to represent these interrelationships in a linear flowchart. The pathways are perhaps better visualized in a circular network as shown in figure 3.6.

In summary, complexity theory is employed in this study to explore and unpick:

a) reality and context (few studies have looked at how complexity makes sense of different realities, context can be complex at one level, simple at another [Gatrell, 2005]);
b) evidence (the value of data, especially secondary data);
c) power (dynamics, power plays and how GIS data can be harnessed to influence thinking).

These aspects relate in part to the key themes identified early on in the study, which have been developed further in response to data collection and analysis. The tool for data integration and presentation, GIS, will now be discussed from a complexity stance.

Figure 3.6: Pathways between inter-related variables in public health decision-making



3.7 Complexity and geographical information systems

The current vogue for evidence-based decision-making could be described as an attractor or a behaviour that exhibits patterns. (Fraser and Greenhalgh, 2001). In order to implement change, for example the incorporation of GIS evidence into the knowledge base for making decisions, Plesk and Wilson (2001) suggest that it might be useful to emulate or parallel attractor states within the system. Here the use of GIS in public health is packaged in an evidence- based practice guise to make GIS more acceptable and attractive to participants in the study. Within the study context it was recognised that participants may in some ways need to be counselled about the implications of GIS approaches. Through this approach, potential fears could be allayed regarding the technology by outlining what GIS is, as well as what it is not. Language and metaphor familiar to the culture in which the participants worked were used in the interviews.

3.8 Complexity and collaboration

Due to the importance of inter-relationships in complex systems the notion of collaboration and working together seems to resonate with complexity thinking. Collaboration enables connections to be made and ideas to be transposed between fields (Geyer, 2003). Various and diverse disciplines are drawing on the precepts of complexity theory to advance learning and understanding in praxis. So in essence complexity is becoming a multi-disciplinary endeavour. The strength and reciprocity of dialogue between other disciplines is unknown.

Byrne (1998) advocates the notion of 'holism' in complexity thinking: the whole system, its internal and external relations and its social and cultural embeddedness. Metaphor is omnipresent in complexity discourse enabling opportunities to apply insight and understanding in other disciplines (Goldenfeld and Kadnanoff, 1999). It was hoped that the use of metaphor may have enabled stakeholders to engage with the use of GIS in an attempt to further collaboration and interagency working.

3.9 Complexity and the case study approach

The case study approach is used to investigate complex ongoing processes (Elliott and Popay, 2000). As Stake (2003, p.134) observes "*a case*

may be simple or complex".

> *The case is a "bounded system"...the case has working parts; it is purposive; it often has a self. It is an integrated system...Functional or dysfunctional, rational or irrational the case is a system. Its behaviour is patterned. Coherence and sequence are prominent* (Stake, 2003, p.135).

The above quotation reflects the underpinning precepts of complexity theory. With the notable exception of the notion of 'bounded-ness' the study approach frames 'the case' as a complex system with elements of pattern and inter-relationships but also the possibility of uncertainty and disorder.

The study employs mixed methods to examine the case using the most appropriate strategy of inquiry to ensure rich data description (Denzin and Lincoln, 2003). As Cooper and associates (2004) assert the importance of understanding process as well as outcomes is critical:

> *...as we move away from a reductionist philosophy towards a complexity view point, a mixed methods (quantitative and qualitative) approach is essential to uncover both outcomes and processes and to capture what emerges, as well as achievement in relation to what was intended* (Cooper, Braye and Geyer, 2004, p.186).

The case study approach facilitates examination of context and relationship whilst adopting a reflexive stance (Lessard, 2007). Anderson *et al.* (2005) encourage the use of complexity theory in case study research as understanding can be gleaned by focussing on the patterns of relationships and interactions of the whole system.

3.10 Limitations of the complexity paradigm

Problems in understanding complexity discourse lie in the common place, everyday usage of the words 'complex' and 'complexity' as adjectives and nouns respectively. Complexity science is much more than just the complex or complicated. This study applies the basic tenets of complexity theory to further meaningful understanding of complex decision-making processes on the health agenda. The approach, which uses metaphor, has been criticised by some for failing to understand complexity theory in its truest form. Gatrell (2005) presents a comprehensive review of complexity theory and its application to health geography, where he debates what complexity can offer to the process of understanding relations between health in time, space and place. He goes on to discuss the inadequacies of complexity theory in relation to the health context, specifically the use of complexity as metaphor rather than

the rigorous application of complexity theory in empirical studies. In summary, Gatrell asserts that it is far easier to theorise about complex systems rather than to apply the complexity paradigm to research problems. Gatrell (2005, p.2669) directs three major criticisms against complexity theory applications:

(i) Failing to make the 'human voice' heard. While qualitative in nature previous empirical studies focus on "*structures and patterns*" to the detriment of human experience.

(ii) Neglecting the issue of gender, few researchers in the field are female despite complexity offering a non-hierarchical approach.

(iii) Fully appreciating the impact of distance, support at the local level is crucial and issues of "*territoriality and sense of identity*" remain pertinent.

This study attempts to address point (i) through the use of semi-structured interviews to express the views, opinions and perceptions of practitioners on the value of GIS as a technology and source of evidence for public health decision-making. Similarly, the issue of gender (point ii) is brought to light as the study is being conducted by a female researcher. These issues will be returned to in chapter 8 and the Epilogue.

Interesting questions arise through the application of complexity theory in the public health domain. Researchers are criticised for taking a model from the natural sciences and oversimplifying it to 'fit' current problems being researched (Plesk and Greenhalgh, 2001). Protagonists might take issue with the notion of complexity within the world of public health. It could be argued that public health as a complex adaptive system is merely a construction framed on negativity and based on the constraints of the biomedical model. Critics of complexity argue that it is merely just another research trend that will go out of date as quickly as it arrived. In this way it would be a mistake to 'chuck the baby out with the bath water' as many of the lessons of complexity resonate with the issues and challenges of modern public health.

3.11 Conclusion

This chapter has attempted to capture and frame the central themes of the study from a complexity viewpoint. The context of the study, public health, is appreciated as superficially complicated but also complex, in the theoretical sense (as demonstrated in table 3.4, public health decision-making as a complex system). Any process involving human actors, such as decision-

making, is necessarily unpredictable with individuals bringing to the process a plethora of different ideas, values, priorities and experiences. GIS does not traditionally belong to public health, this represents a possible barrier and, therefore, an added complication. The study aims to capture the essence of the value of GIS mapping to public health and to understand its reception, acceptance and usefulness within the public health decision-making community. Elements of complexity reverberate throughout the thesis as illustrated in the choice of case study in the research design; the challenge of reconciling both quantitative and qualitative aspects of data collection and the use of GIS to foster interagency collaboration.

The dominance of the biomedical model has meant that in public health research the epistemological lens has been so well focused that the theoretical perspective is taken as read and seldom discussed explicitly. This reductionist approach has attracted criticism for its closed and myopic way of viewing the world, which fails to take into account the totality of a phenomenon by breaking it down into its component parts. The machine metaphor is commonplace in methods of understanding and is entrenched in the biomedical and strictly scientific paradigms of research. Complexity offers an integrative (Gallagher and Appenzeller, 1999) approach to research that extends beyond the traditional (and safe) reductionist forms of enquiry. Given the embryonic stage of theoretical development the basis of complexity should be expanded further and grounded in empirical research. There is a wealth of opportunities within public health, and beyond, to apply concepts and develop theoretical insight. Complexity theory provides the foundations for the study and the concepts of complexity are embedded throughout the thesis; this is demonstrated in the proceeding chapter, methodology and methods.

It is clear and generally well accepted that complexity theory is not the panacea for advancing public health research. Like any other, the theory has limitations and Gatrell (2005) points to the need for further empirical studies to advance the debate. Complexity theory does, however, challenge erroneous assumptions and misconceptions inherent in modernist discourse whilst also providing a theoretical framework, which acknowledges and accepts, rather than ignores or denies the complex and difficult issues in an attempt to forge a path through the thick and thorny public health terrain. Complexity theory provides a sounding board for positive and proactive solutions to difficult

problems by recognising that a multifaceted issue with embedded, dynamic systems and non-linear behaviours can, indeed, be manageable. Rather than retreating or withdrawing from a certain issue because it seems unworkable or overwhelming, complexity theory acknowledges these difficulties and provides a compass to negotiate a path forward. By providing a framework for multi-faceted context embedded problems, complexity attempts to make sense of the intangible by recognising the workings of the system as a whole.

"If poorly used (or poorly made) a well intentioned tool can do more harm than good"

(Krieger, 2003, p.385).

Chapter 4: Methodology and Methods

4.1 Introduction

The case study approach is often criticised for being a catch all category for studies that do not fit the criteria for other methodologies. In this chapter the justification for the use of case study is argued whilst also recognising the shortcomings of this particular methodology. The chapter begins within an overview of the case study approach including detail on how the study developed from a linear process into a more organic and reflective endeavour. Arguments for employing a multi methods strategy within a case study design are laid out and the methods undertaken (GIS mapping and semi-structured interviews) are described and critiqued. Background information relating to GIS technologies and the use of GIS mapping in the health context is then presented before considering the benefits and limitations of secondary data use. The theoretical framework of complexity, which has evolved within the research process, is rationalised with respect to the methodology employed. Finally, strategies relating to data collection and sampling are discussed and some of the pertinent ethical issues in the study are critically debated.

4.2 Methodology: case study research

4.2.1 Overview of study design

The methodology employed is case study research, where the case is a specific feature (decision-making processes), which is explored in the context of public health. The case example of 'potential childhood lead exposure in Newcastle upon Tyne' is used first to explore the intricacies of GIS as a method of data integration and presentation and second to examine how GIS is valued by public health decision-makers. Stake (2003, p.153) describes the issue of "*cases within the case*" and emphasises that the case should be chosen based upon the "*opportunity to learn*" rather than specifically sampling on the basis of the case attributes.

Case study analysis, in this instance, allows the researcher to investigate the phenomenon *in situ* using a multi-method approach (Robson, 2002). The study was initially conceived with a two part design. Phase I involved quantitative mapping of historical, environmental, demographic and health data using GIS. Phase II, on the other hand, employed qualitative methods to

facilitate understanding of the value of GIS maps in public health decision-making processes. As the study developed, this linear design with two distinct phases, linked only by the use of GIS maps, did not seem to provide the best fit. Rather, a more dynamic, cyclical model made more sense, where the exploratory mapping phase informed the interviews but then data from the interviews were fed back into the mapping to develop a critique. Data exchange was reciprocal and the study design acquired a more dynamic feel where explicit links were made between the early and later stages (see figure 4.1). In essence the preliminary mapping phase informed both the interview phase and the mapping critique, which were linked by a feedback system.

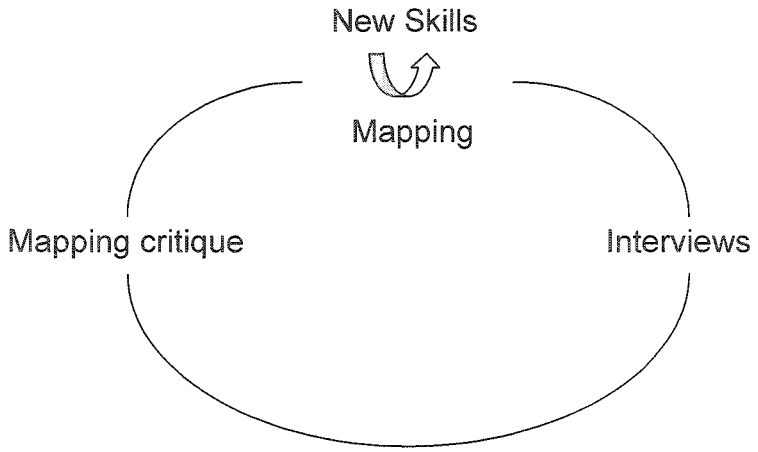
Figure 4.1: Development of the study design

Early Design: a linear process

Phase I (GIS mapping) → Phase II (qualitative interviews)

Revised Design: a cyclical process

A critique of the use of GIS in public health decision-making



It would be pertinent here to clarify the role of GIS within the case study. GIS was used during the mapping exercise to draw together and integrate a range of heterogeneous data sources relating to the issue of childhood lead exposure. A mapping report was produced from these explorations, which served as stimulus material for debate during the interviews. Throughout the interview phase, GIS was used as the instrument for display of data produced

during the preliminary mapping stage. Interview discussions, with stakeholders involved in public health practice, centred around the data produced using GIS, which demonstrated the diversity of GIS functions but also highlighted the limitations of using maps in evidence-based thinking.

The involvement of GIS is embedded throughout the project: it is employed early on to manage, manipulate and display data relating to the case example and then used later in the study as example material to open discussion and to stimulate debate. Building on the core public health concept of collaboration, the potential for using GIS to facilitate sharing of data between agencies was also examined.

By using the case study approach the full extent of the phenomenon could be scrutinized from a range of different angles based on heterogeneous sources of data (Yin, 2003). Furthermore, the research strategy allowed for a more flexible and iterative approach to the study question. It is particularly fitting in this instance because the study draws on theory from a number of different fields including geographical information systems, public health, sociology and political science.

The project is both an exploratory and a descriptive case study. It is descriptive in the sense that the work assimilated existing data to provide a novel and rich depiction of a current public health issue. Moreover, the case study is exploratory in that it attempted to understand the value of GIS mapping as a tool within the context of public health practice. In terms of the case example of lead exposure the study considered diverse angles of the phenomenon including the social, environmental, historical and health aspects of childhood lead exposure. Another feature of the case study approach is its capacity to uncover unexpected and unpredictable events (Anderson *et al.*, 2005), which is congruent with the underpinning framework of complexity.

Yin (1993) suggests that case study is the methodology of choice when phenomenon and context cannot easily be separated. Indeed the phenomenon of GIS evidence in decision-making pathways cannot easily be understood without considering the context of public health. It is important to mention here that as the study evolved, there was a case shift from a focus on the case example childhood lead exposure to an interest in the benefits and limitations of GIS maps as evidence themselves.

4.2.2 Appropriateness of the methodological framework to the study

The study employs an eclectic approach towards methodology, incorporating both quantitative and qualitative[6] methods in a case study design. The precursory mapping phase involved collection, collation, appraisal and mapping of numerical secondary data. Before data were incorporated into the GIS an appraisal process akin to systematic review or meta-analysis was undertaken. As in systematic review, secondary data were collated and filtered using specific inclusion and exclusion criteria and then appraised through a rigorous framework incorporating questions relating to validity, reliability, completeness, integrity and confirmability (see figure 4.3).

The output maps were produced through an extensive process which involved (i) locating data; (ii) negotiating access to data, which were sometimes not in the public domain (for example, birth weight data, supplied by the Regional Maternity Survey Office [RMSO]); (iii) translating attribute data (referenced using National Grid co-ordinates, or ascribed to an administrative ward) from tabular format to produce shape files and (iv) appraising the data before inclusion in the final GIS output. Throughout this process there was potential for interpretative bias, for example one reviewer's conceptualisation of what data should be incorporated into the GIS might be different to another reviewer assessing the same information. It was therefore critical that a robust framework for dataset inclusion was employed (see figure 4.3). The complexity paradigm helped to ground and embed this process of critique which could be thought of as containing both subjective and objective elements.

The value of GIS in the evidence base for decision-making was addressed in the qualitative stage of the study through semi-structured interviews. The study comprises elements of order and linearity (overlay analysis of quantitative datasets) and disorder (participant perception of GIS mapping). Drawing parallels with complexity theory, GIS facilitates understanding of the inter-relationships between datasets rather than simply focussing on the data alone. The interviews were conducted in an adaptive environment where participants responded to the map stimuli and opinions relating to GIS mapping emerged. The links between the study framework, methodology, methods and aspects of the complexity paradigm are illustrated in

[6] Here study the term 'quantitative' is used to refer to numerical data, which have been referenced spatially and mapped using GIS. Conversely, the term 'qualitative' refers to data pertaining to views, opinions and beliefs, gathered through interview discussions.

figure 4.2. This diagram represents the relationships in a linear format for ease of interpretation but it should be remembered that the key phases of the project were contingent and progress was reflective. Techniques to establish validity and reliability are discussed in the following chapter, Data Analysis.

4.3 Overview and justification of methods employed

The project is principally a descriptive study concerned with understanding the value of geographical information systems in public health decision-making. The study uses the example of lead contamination in the district of Newcastle upon Tyne to explore the usefulness of GIS technologies and GIS maps to public health practitioners.

GIS has been used to examine the geographic areas affected by lead and the type of contamination observed but has no power to attribute cause and effect to health and development conditions thought to be related to lead exposure. The study is exploratory and draws together multiple disparate datasets to produce a visualisation of lead contamination in Newcastle upon Tyne. The value of integrating multiple disparate data using GIS was examined in the second phase of the study where multiple agencies were interviewed about their feelings and beliefs about the use of GIS to promote inter-agency working, using childhood lead exposure as a case example.

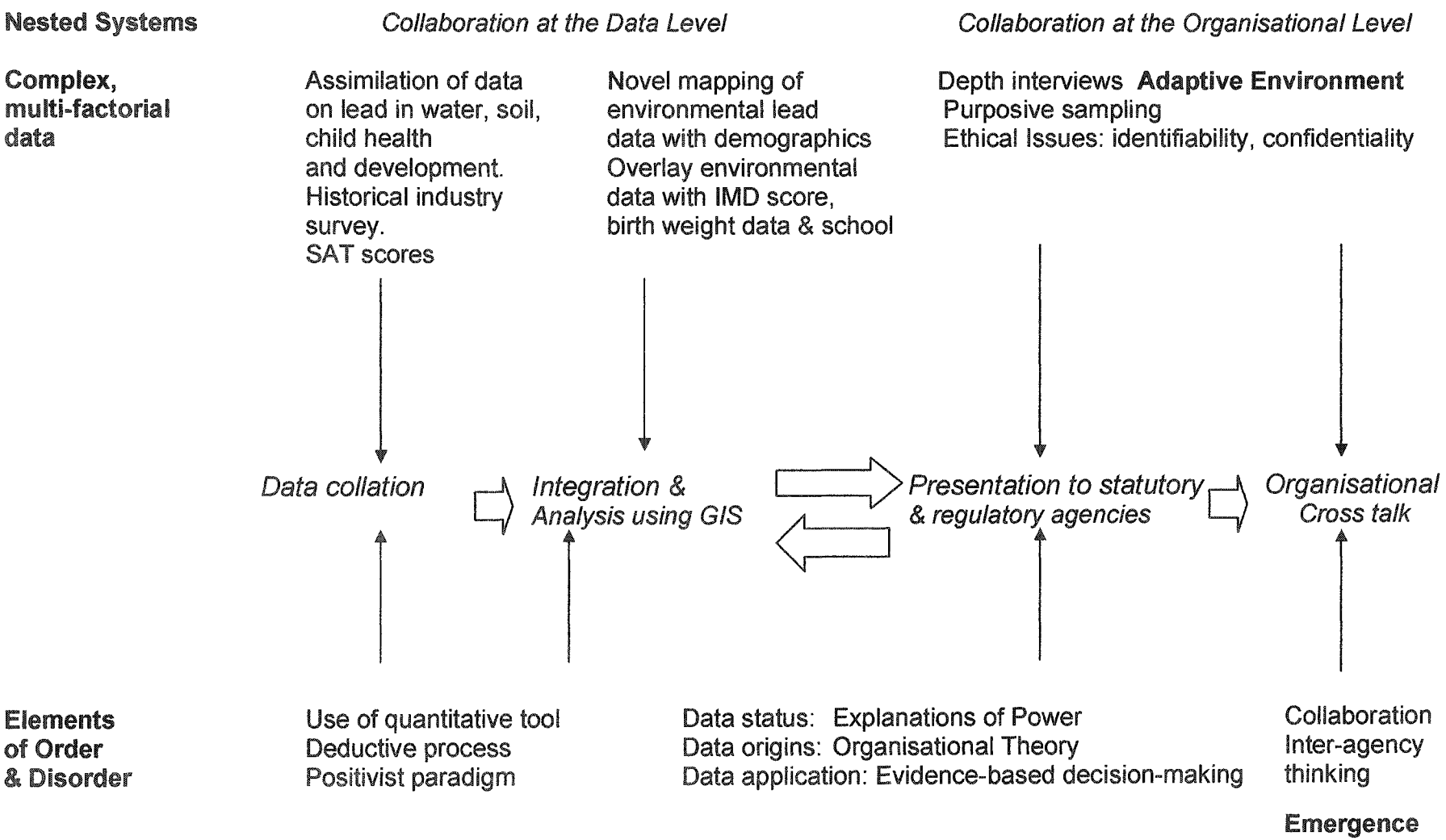
The study is unique and unconventional in that it is considering a public health issue from a number of different angles not just the traditional epidemiological stance. By working at the interface between geography, epidemiology and public health studies, data can be integrated and there is potential for ideas from different disciplines to be combined. The study seeks to add to knowledge by transposing concepts of complexity theory into the area of public health to enable new understanding and a move away from traditional reductionist and mechanistic thinking. Literature from other fields has demonstrated how inter-disciplinary collaboration from seemingly unrelated subject areas can lead to novel ideas and innovations. An example includes a successful partnership between anthropologists and designers, which allowed ideas and concepts to be shared, developed and advanced into new and exciting territory (Squires and Byrne, 2002).

In the past twenty years the use of GIS in a health context has been examined in detail and the concepts of health and place and the inter-

relationships between the two have been explored and debated. A number of studies, mostly conducted in the United States and Australia have examined the issue of lead contamination using GIS (O'Dwyer, 1998; Reissman *et al.*, 2001; Weintraub, 1998). These studies have tended to use a narrow environmental epidemiological approach. Few such studies have been conducted in the UK since the 1980s, those that have, usually considered only one aspect of the problem, namely soil contamination. In this respect the mapping exercise presented here was novel in that it considered childhood lead exposure using a broad, multifaceted approach to reflect the multi-factorial nature of the problem. Complexity theory provided an appropriate framework with which to orientate the study.

It could be argued that a qualitative design would be a more fitting approach to the overall study question but without an in depth understanding of the minutiae of the GIS toolbox the researcher could not have been in the best position to discuss with practitioners the benefits and shortcomings of GIS in the public health setting. The case study approach was therefore adopted to allow for a mixed methods design with flexibility. Anderson *et al.* (2005) assert that case study is well suited to research within the complexity paradigm as it enables a focus on inter-relationships and connections within the system.

Figure 4.2: Understanding collaboration in the policy process: from producing evidence to making decisions – a complex process (aspects of complexity in bold)



4.4 GIS as a tool for decision-making in public health

Mapping of disease or contamination by place can be a useful method of visualising patterns of inequalities in health between different geographic localities and demographic subpopulations (Järup, 2000, p.432). The nature of these systems allows multiple and varied data to be brought together and analysed and the visualisation and overlay of different datasets can allow spatial patterns to be discovered that might have been less obvious when using more traditional approaches. Cromley and McLafferty (2002, p.13) suggest that "*GIS maps can become metaphors for the social and environmental conditions that are 'contained' in geographic space*". Krieger (2003) urges caution in the use of geographical information systems in epidemiology. Whilst acknowledging the value of GIS in understanding the involvement of place in a particular public health phenomenon, the author emphasises "*the need to document the validity of GIS methods and provide conceptual justification for the geographical levels chosen*" (Krieger, 2003, p.384). The paper also points out sources of selection bias and systematic bias introduced by errors in geocoding (that is tagging particular points with a geographical reference). Orford *et al.* (2002) highlight further problems associated with converting paper records into digital format for manipulation in GIS. This was a particular concern when considering the historical archive records.

The use of GIS, in this instance, explored the distribution of possible sources of environmental lead in Newcastle upon Tyne. The exercise enabled the researcher to become more familiar with the GIS toolbox and drew together data to further understand the complex, multi-factorial issue of potential childhood lead exposure. The GIS visualisations represented new ways of making sense of existing datasets and were presented to public health decision-makers to demonstrate the benefits (and also the shortcomings) of GIS as a method to explore and critique data, to display and communicate information and to present evidence to feed into decision-making pathways. These stakeholders may have had access to some of these data but time limitations, lack of expertise or equipment may have precluded their involvement in analysis, manipulation or display using GIS. Moreover, decision-makers do not necessarily have the opportunity to access these multiple disparate data sets together and to interrogate them using overlay analysis.

4.5 Descriptive and integrative mapping using GIS

4.5.1 Overview of methods

Public health practitioners advocate a broad definition of health involving multiple inter-related physical, social, psychological and environmental determinants. GIS can be used to draw together a range of different data to examine the relationships between determinants. It is the application of GIS in the context of public health rather than the development of GIS in its own right, which is important in this project. GIS has been used to integrate and interrogate a range of data to attempt to understand the totality of the phenomenon of environmental lead contamination in Newcastle upon Tyne. With any new technology it can be tempting to become carried away with the intricacies of the method, to go off on tangents and to become lost in unnecessary detail. It was, therefore, critical that the researcher was aware of this potential pitfall to ensure that the project remained driven by the study aims and objectives rather than by the GIS methods employed.

An important consideration when using GIS is how the quality of the end map is entirely dependent on the reliability, validity and completeness of the raw data input into the system. This issue, which is commonly referred to as 'garbage in, garbage out') is particularly pertinent here as the data involved are secondary and are collected and collated from a range of different sources. It was essential that data were critiqued before being incorporated into the GIS. The framework used to appraise the data is shown in figure 4.3 below. The issue of scale is especially pertinent as spatial patterns that exist in the data may be missed unless the resolution is fine enough (Albert, Gesler and Levergood, 2000). Lower level super output areas (SOAs) instead of ward boundaries were used to address this potential pitfall. Although it should be noted that not all data included in the mapping exercise were available at output area level.

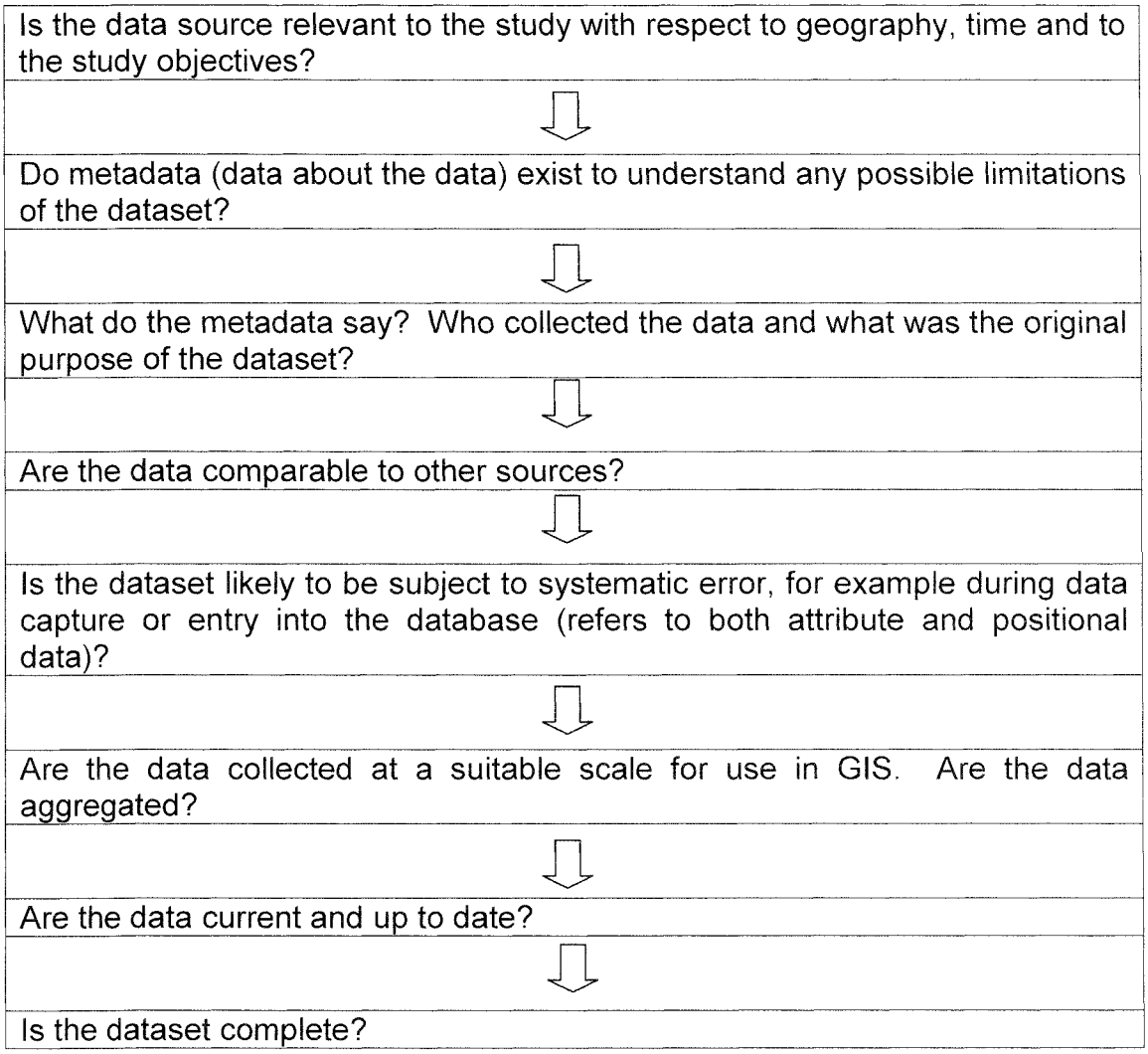
Many authors draw attention to the ecological fallacy, which is described by Albert, Gesler and Levergood (2000, p.89) as

> *...a catch all term for errors in results obtained by making inferences from data collected at one scale to individuals or communities aggregated at other scales.*

In this study, data were collected, analysed and discussed at a population scale and no inferences have been made at the individual level. Similarly, considerable debate centres around the 'modifiable areal unit problem', as

described by Openshaw in 1984, whereby the use of arbitrary units can distort visualisation of data and produce artificial spatial patterns which are not a result of the phenomenon under study (Järup, 2004; Martin, 1996, p.145). Martin (1996) suggests that there are two inter-related issues to address: the scale problem (the level of resolution, or number of units) and the aggregation problem (the grouping of area into defined areal units or zones). Some authors advocate the use of a tailor made grid system to address these concerns (Järup, 2004). Here the availability of demographic data at the level of census units and the proposed presentation of the assimilated data to policy makers involved in local government were key drivers towards the use of administrative boundaries that would be clearly recognised by the target audience.

Figure 4.3: Quality framework developed to critique data sources for inclusion in the GIS



ArcGIS® was used to interrogate the data collected using the following techniques: map overlay, choropleth mapping and spatial query. The GIS

overlay operation allowed datasets which are not usually seen together to be visualised in one map, making it possible for relationships in the data to be identified and drilled into further (see figure 1.1, chapter 1). Again it should be emphasised that the mapping exercise was principally descriptive in nature and did not attempt to explore causality or suggest that there are associations between lead in the environment and child health and development indicators.

4.5.2 Use of secondary data

In the grand research spectrum secondary data are given relatively low importance and potentially valuable data are disregarded after being used to support a single publication. Indeed Macintyre and associates (2001, p.224) highlight what they term *"a striking lack of use of existing, government funded datasets and techniques for searching for relevant information and avoiding bias"*. Daly, Kellehear and Gliksman (1997, p.123) observe that researchers have a tendency towards primary data collection as they seem to equate this with originality. In contrast, the authors argue that secondary analysis of pre-existing data can be just as original as empirical data collection if the right questions are posed.

During the mapping exercise data from multiple disparate sources were integrated to gain a broader perspective of the issue of childhood lead exposure in Newcastle. One of the novelties of the mapping exercise lies in the idea of combining existing data in different ways to provide new insight into an old problem. Analysis of secondary data is advantageous for several reasons. First, it makes use of existing data that might otherwise have been disregarded after empirical analysis (Robson, 2003). Second, there are often plentiful supplies of unique, longitudinal data and reliability can easily be established (Daly, Kellehear and Gliksman, 1997). Third, collection of secondary data can be quicker, cheaper and less labour intensive compared with primary data collection (Robson, 2003).

There are, however, several caveats associated with collection and analysis of secondary data. The data are likely to have been collected for a different purpose so may not be amenable to analysis. In addition the researcher has little control over data quality and if there is a dearth of metadata available it may be difficult to quantify possible sources of error or bias. It has been concluded, therefore, that: "*secondary data are only as good as the research that produced them*" (http://www.csulb.edu/~msaintg/ppa696/ 696scond.htm).

From a complexity stance, secondary data analysis and synthesis are adaptive processes in which the constructs of data quality and availability act as attractors or internalised laws. Daly, Kellehear and Gliksman (1997) emphasise that the findings of secondary analyses are unlikely to be generalisable and should only be interpreted within context. Despite these limitations a range of data were collected and appraised using the quality framework set out in figure 4.3 before incorporation into the GIS. The secondary data collated for use in the GIS mapping exercise are laid out in table 4.1 below. Information relating to data critique is presented later in the thesis, figure 6.1, Chapter 6.

Table 4.1 Secondary data collated for GIS integration purposes

Dataset	**Source & Description**
Water Lead Sampling	Random Sampling by population density.
Soil lead sampling 1	Aspinall *et al.* study (1988)
Soil lead sampling 2	Byker Incinerator Study (2003)
Index of Multiple Deprivation (IMD)	Office of the Deputy Prime Minister (ODPM)
Historical Industry.	Ordnance Survey Maps for the following epochs: 1856, 1898, 1910, 1930s, 1960-1980
House age	Shapefiles produced from historical map data and validated using street by street surveys
Birth weight	Data collected from Regional Maternity Survey Office (RMSO)
SAT score	Collated from publicly available standard attainment tests (SAT) data
Road Network data	Office of National Statistics data and Local Authority data
Historical Infant Mortality Data	Historical MOH Reports using 1800s boundaries (Digimap)

In consideration of the map overlays, issues arise around possible contentious relations presented in the maps. There is significant debate over definitions of intelligence and how to measure intelligence and educability in children. With respect to the use of standard attainment target (SAT) scores as a measure of intelligence the constructs of validity and reliability are ambiguous. Do SAT scores actually measure intelligence and do they produce consistent and reproducible results between different geographical areas? Ray (2000, p.281) suggests that although SATs are accepted as valid, in that "*they are testing*

what they appear to be testing", levels of reliability tend to be low as it is difficult to ensure that test conditions are constant between schools. Furthermore, the factors that influence intelligence are multi-fold and include social, cultural and economic as well as familial dimensions. Within the context of complexity, intelligence might be regarded as an emergent property, effecting and being affected by a range of factors within a nested system (Byrne, 1998). These might include: individual components (such as genetics), environmental factors such as family circumstances (for example socio-economic status or parent's education) and wider societal variables (including equitable access to high quality teaching).

Fulton and colleagues (1987) listed a number of confounding variables to consider when examining the association between lead exposure and loss of intellectual development namely: family circumstances/absence of a parent, socio-economic status, parent occupation and education level, the child's position in the family and the overall health of parents and child. Similarly, birth weight is thought to be mediated by a multitude of inter-related factors many of which are contingent across different systems. Societal factors include housing, unemployment and access to primary care (Kogan, 1995), which in turn influence more proximal, environmental variables such as social support networks and from a physical perspective exposure to infectious disease or environmental toxins. Ultimately, both systems have an effect on the individual who is also susceptible to behaviour or lifestyle choices such as diet and smoking (Kogan, 1995). So any attempt to uncover an association between lead exposure and reduced educability or indeed lead uptake during pregnancy and birth weight would be riddled with difficulties relating to these confounding variables.

Again it should be reiterated that the mapping exercise does not attempt to address this issue of causality. The model of complexity provides a constructive and meaningful lens through which to view socially embedded, dynamic and multi-factorial public health problems. Through the use of complexity theory and mixed methods, the study attempts to move away from traditional ways of thinking to embrace a whole systems approach which attempts to understand rather than explain. Instead of attempting to allocate cause and effect or to reduce intricate and adaptive systems to simple, linear pathways, the methodology employed has greater potential to uncover subtle

inter-relationships to gain a clearer insight into complex problems.

4.5.3 Purpose of the mapping report

The report (see appendix I, volume II) served as an example of GIS mapping for data integration and visualisation purposes and was particularly useful when a participant was unfamiliar with mapping principles and GIS techniques. Moreover, the report acted as a vehicle to initiate debate in the interview sessions and helped to illustrate specific concepts and ideas. Whilst producing the report it was necessary to consider the audience for whom it was aimed. The intended audience was the public health community, that is individuals working for organisations whose work impacts either directly or indirectly on the health of the public. There would, therefore, be varying levels of understanding of the principles and central tenets of GIS and differing levels of familiarity and experience with the software.

Consequently the report was divided into three sections: the first outlining the issue of childhood lead exposure and giving basic information on GIS mapping to set the scene, the second included background maps to frame the issue and to contextualise the debate and the third and final section contained map overlays to stimulate discussion. It is noteworthy that no interpretative scripts of the maps were included as the aim was to explore how the maps were understood or possibly misunderstood by participants.

4.6 The qualitative phase

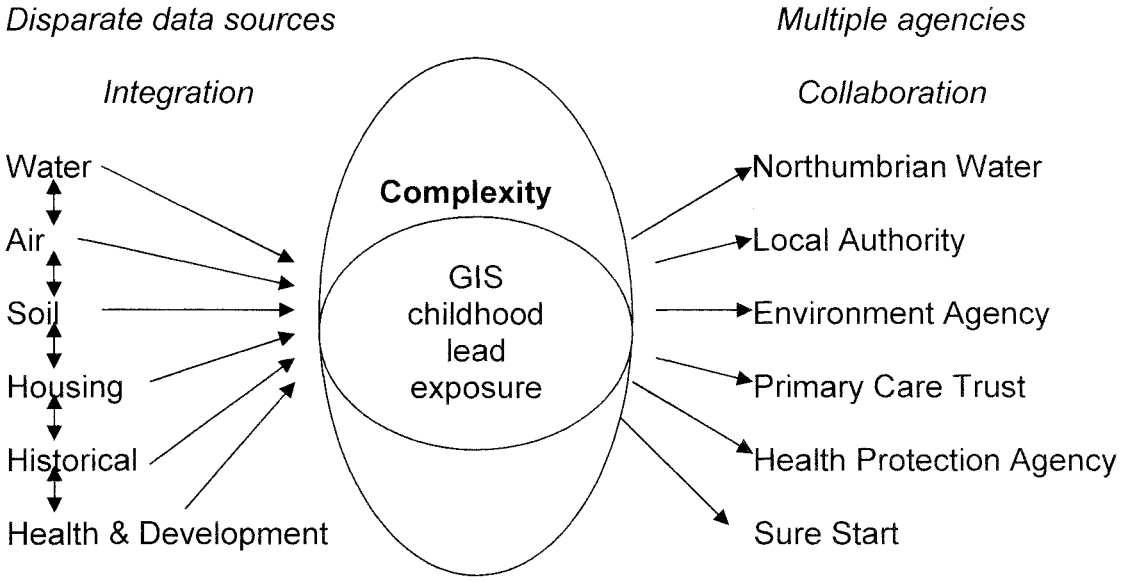
4.6.1 Semi-structured interviews

The value of integrating data using GIS was explored in the second phase of the study where key personnel from multiple agencies involved in public health, in the broadest sense, were interviewed about their thoughts and beliefs regarding GIS as a tool in evidence-based decision-making processes. The study reflects the interdisciplinary nature of public health both in data integration at the information level and data presentation to decision-makers at the organisational level. Both stages relied upon and were underpinned by the use of GIS (see figure 4.4).

The qualitative phase of data collection and analysis sought to understand how GIS technologies are used and are valued in the public health evidence base. Moreover, semi-structured interviews were conducted to

explore how senior decision-makers engaged with maps as evidence for decision-making processes and what they felt were the key advantages and limitations of maps as evidence. An additional objective was to understand decision-makers views regarding the use of GIS to promote data sharing and to facilitate inter-agency working. The interviews examined the use of GIS visualisations, in contrast to statistics and graphs, in the description and communication of a contemporary public health issue, namely potential childhood lead exposure.

Figure 4.4: The interdisciplinary stages of data integration and data presentation: the agencies sampled reflect the varied sources of data accessed to produce the maps.



Qualitative methods are deemed more relevant when addressing questions relating to participant's thoughts, perceptions and beliefs (Robson, 2003). Adopting a complexity perspective, Sarantakos (1998, p.46) recognises that

> *...the researcher and the researched are two equally important elements of the same situation. Respondents are not reduced to variable units of hypotheses but are seen as parts of the whole. Reducing people to numerical symbols and statistical figures results in a loss of a perception of the subjective nature of human behaviour.*

Semi-structured interviews were chosen as method of choice as they afford more anonymity compared with focus groups (Smith, 2007). Here the questions centred round the value and usefulness of GIS data in decision-making processes. It was thought that the incorporation of semi-structured interviews in

the case study could lead to new insights on the perceived value of GIS as a tool in public health practice and may raise awareness of the advantages and shortcomings of using GIS as a tool in public health. As a secondary objective the collection of existing descriptive data on childhood lead exposure in Newcastle upon Tyne could illustrate gaps in the knowledge base and may aid the design of future studies on the issue.

A survey approach to data collection was inappropriate in this context as it was felt that a survey would yield rather superficial findings and would only scratch the surface of some of the core themes under investigation. Semi-structured interviews were chosen rather than structured interviews as it was thought that this method of data collection would be less regimented and less prescriptive (in keeping with the central tenets of complexity theory) and would enable the participant to take on a more involved role in the study. Furthermore, semi-structured interviews provide a more flexible mechanism to drill down into issues that concern or interest the respondent most (Denscombe, 2003) to really understand how meaningful GIS data are to public health practitioners[7]. The content of the interview and the questions posed to participants were informed by the key themes uncovered by the mapping phase (outlined in figure 4.7).

The study crosses the disciplinary divide both intellectually and pragmatically (see figures 4.2 and 4.4) by employing concepts of complexity theory. The mapping of environmental and population data using GIS represents a novel way of integrating disparate sources of data and understanding the complex inter-relationships between data. From the participant's perspective, the interviews may have had some educational value and there was potential for the study to introduce GIS as a vehicle for promoting interagency collaboration.

4.6.2 Participants and sampling

Organisations, rather than individuals, were sampled purposively from agencies involved in decision-making relating (directly or indirectly) to public health. The selection criteria are set out in figure 4.5. At the individual level, participants were required to have a strategic decision-making role and be involved, at some level, with the policy process. Members of the Lead Task

[7] The terms decision-maker and practitioner are used synonymously

Force Group were excluded as they already had background knowledge of the case example and thus may have had vested interests in the study outcomes. In addition, there was a need to maintain ownership and control of the study objectives.

Figure 4.5: Selection criteria

Inclusion Criteria
Membership of an organisation with an interest in public health (the environment, children's health);
Senior managerial role or senior data management and analysis role;
Decision-making responsibilities;
Active contribution to policy or the evidence base for policy-making.

Exclusion criteria

Stakeholders involved in the Lead Task Force Group.

Drawing on the definition of the 'public health workforce' employed by MacKian and co-workers (2003) participants included: decision-makers at all levels ranging from community development workers through to public health consultants and perhaps most interestingly decision-makers involved in public health who might not have been aware of their role in this context. For the purpose of this chapter the term 'participant' is used to refer to an individual who fulfils the selection criteria and therefore can potentially be interviewed whereas the terms 'respondent' and 'interviewee' are used synonymously to refer to someone who has undergone the interview process.

Organisations involved in contributing secondary data for analysis in the mapping exercise were sampled initially and included in alphabetical order: the Environment Agency; Government Office North East; the Health Protection Agency North East; Newcastle Local Authority; Newcastle Primary Care Trust; Northumbria, Tyne and Wear Strategic Health Authority; Northumbrian Water Limited and Sure Start. Other organisations were selected through snowball sampling (see figure 4.6) including: ALPHA an NHS associated Public Health Consultancy; the Department of Health; Durham and Tees Local Strategic Partnership; Gateshead Primary Care Trust; North East Assembly; North East Regional Information Partnership; North Tyneside Local Authority; North Tyneside Primary Care Trust; Northumbria University; Sedgefield Primary Care Trust; South Tyneside Local Authority; Primary Care Consortium and the Public

Health Observatory North East. In total, 25 agencies were approached and 21 participants consented to be interview indicating a response rate of 84 per cent.

Contact with appropriate participants was established first by email and if no response was received within a week, by letter of invitation. After three attempts at making contact (two emails and a letter) another participant from the same organisation was approached. An audit trail of potential participants contacted and those who consented to be interviewed, and those who refused, was recorded in the study database and systematically updated (see appendix VI). Introductions were made by the chairperson of the Newcastle Lead Task Force to enhance the researcher's credibility and to underline the importance of the work (see Appendix X). To maintain anonymity and confidentiality, it was crucial that caution and care were exercised during the process of identification and recruitment of participants.

4.6.3 Data Collection

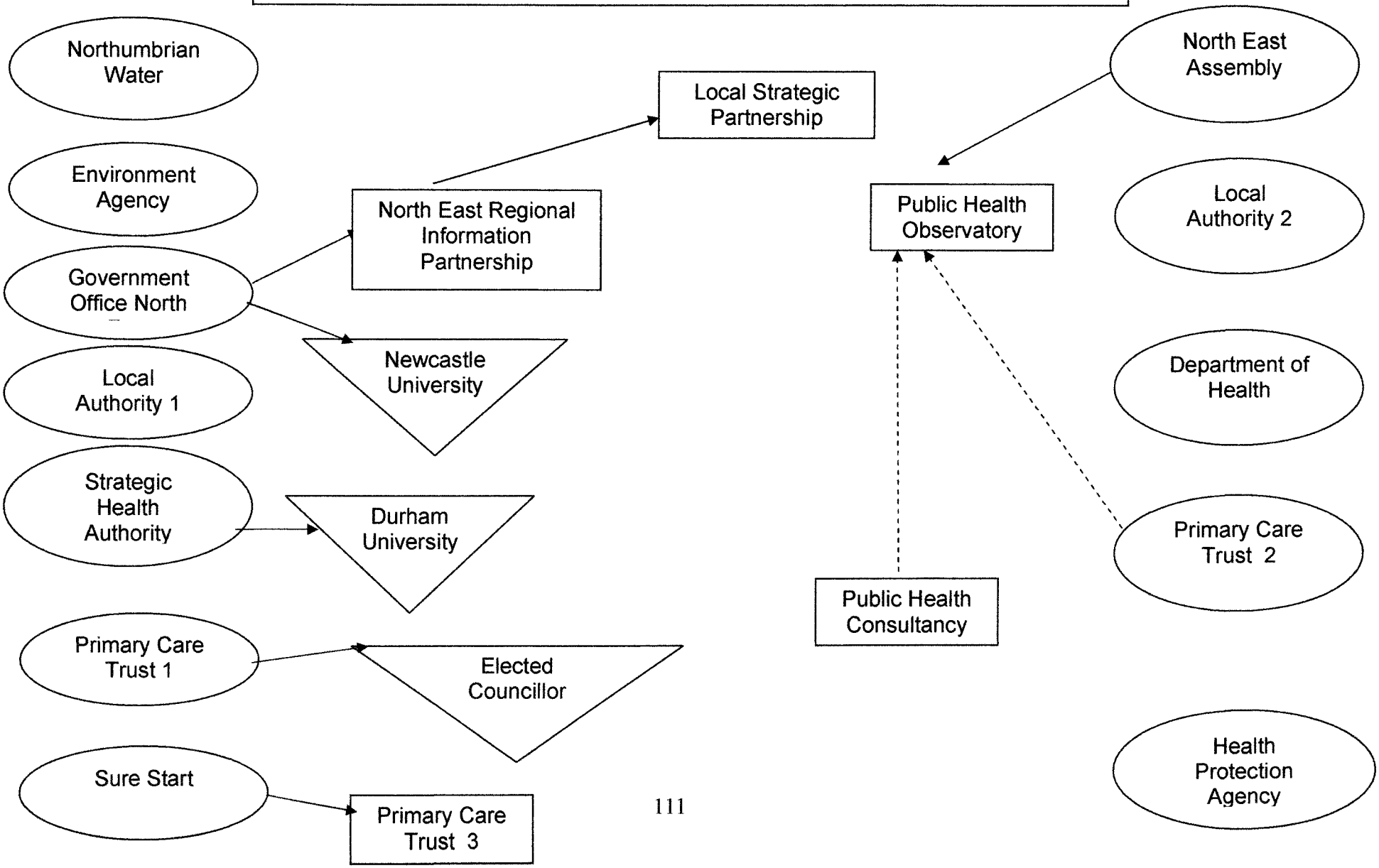
The mapping report (see appendix I), which included a number of descriptive maps together with background information, was sent to participants prior to the interviews and served as a stimulus for debate in the interviews as well as illustrating the central concepts of GIS and the functions of the toolbox. Interviews were recorded and transcribed with the participant's permission. Participants had the right to decline to answer particular questions and to ask for certain parts of the interview to remain confidential, this was explained in the information sheet (refer to appendix III) and reiterated during the interview.

It was emphasised that the purpose of the interview was neither to challenge the participants beliefs nor was it to influence what decisions were made regarding childhood lead exposure. Before obtaining informed consent (see appendix IV) from potential participants it was highlighted that the study's main concern was with 'the process' of decision-making: how decisions are made, on what evidence they are based, where GIS data are used, or could be used, and what additional data are required for future decisions. Essentially the interviews sought to disentangle the complex matrix of information upon which public health decisions are made and to uncover if and how GIS data could fit into those pathways. The interview schedule explored (i) data status, drawing on explanations of power; (ii) data origins, drawing on organisational theory; and (iii) data application drawing on concepts of evidence-based decision-

making.

The questions were developed through analysis of the data gathered during the mapping exercise and reflect constructs of complexity as shown in figure 4.7. An interview schedule was developed from these central themes and is included in appendix V. It should be noted that questions were added as the interviews progressed when interesting ideas were highlighted and new themes emerged. Questions were adapted for participants in different fields due to varying levels of background knowledge and the contrasting priorities and agendas of the organisations involved. The study offered individuals, in experienced positions, the opportunity to step outside their area of work to consider ideas that might be foreign or new to their own organisational culture.

Figure 4.6: Map of sampling framework
Ovals = purposive sampling; rectangles = snowball sampling; triangles = declined to participate



One pilot interview was conducted prior to commencing data collection. The purpose of the single pilot interview was to test the audio equipment and to practice interview technique rather than to amend and edit the interview schedule. Semi-structured interviews were recorded and field notes were made to record any behaviours, facial expressions, gestures or other notable events that were non-auditory. Audio recordings and interview transcripts were stored securely in the University and will be destroyed two years after completion of the study.

Figure 4.7: Topics for discussion in semi-structured interviews

Aspects of order and disorder in ways of knowing
Your organisation and decision-making
Evidence-based decision-making
Use of traditional quantitative data versus qualitative data
The need to attribute cause and effect
Hierarchies of evidence

GIS and the importance of inter-relationships
Status and use of GIS in public health
Examining inter-relationships between elements rather than focusing on the elements themselves

Maps as evidence
Use of GIS maps as sources of evidence in decision-making
GIS methodology or method
Advantages and disadvantages of using maps as evidence

Mapping Report using GIS to integrate data on childhood lead exposure
Interpretation on data presented in the report
Thoughts on the presentation of data as map overlays
If these maps are not useful, why not? What further data are needed?

The emergence of GIS as a tool for interagency collaboration
Barriers to collaboration
Using GIS as a means to promote joined up thinking between agencies

Originally eight interviews were planned but snowball sampling led to the sample size escalating to twenty-two interviews with twenty-three participants (one group interview was conducted). The sampling criteria did stay constant but the diversity of emerging themes resulted in the recruitment of further participants. Details of the interviews conducted are set out in figure 4.8. Interviews were conducted in the participant's own surroundings usually within their organisation (with two exceptions where for practical purposes the

interviews took place at Northumbria University). Face to face interviews enabled an opportunity to probe deeper into interesting or pertinent responses. One telephone interview was conducted as the respondent was not currently based in the North East. Telephone interviews are advantageous in that the researcher can reach geographically distant participants, without incurring costs in terms of time and travel. Boland *et al.* (2006) suggest that respondents may also react positively to the 'perceived anonymity' afforded by telephone interviews.

Field notes were made during and immediately after the interview encounter. Even the smallest actions or non-verbal details, which may at first have appeared inconsequential or prosaic, were recorded in the interview field notes. Following an approach set out by Miles and Huberman (1994) field notes were recorded in contact summary sheets (see appendix VIII) to review the main issues explored in the session and to identify emergent themes to be taken up in subsequent interviews. The contact summary sheet also included the researcher's own thoughts and feelings about the interview encounter. These feelings and thoughts on the interview process were elaborated upon in a reflective research diary. The research diary (see excerpts in appendix IX) helped to document, explore and understand any material that was not recorded on the interview tapes including non-audio data as well as the interviewers interpretation of the encounter.

The study database, contact summary sheets and research diary (see excerpts in appendices VI, VIII and IX respectively) together served to provide an audit trial for transparency and to enhance rigour as discussed in section 5.5. Only the researcher and supervision team had access to the research data including transcripts, field notes and thematic analyses.

Figure 4.8: Summary of interviews completed

Organisation	Role within the Organisation
Department of Health	Researcher
Environment Agency	Senior Manager
Environment Agency[8]	Data Analyst
Government Office North East	Data Analyst
Health Protection Agency	Senior Manager
Local Authority (joint interview)	Senior Manager x 2
Local Authority	Senior Manager
Local Authority	Manager
Local Strategic Partnership	Manager
North East Regional Information Partnership	Senior Manager
North East Assembly	Senior Manager
Northumbria, Tyne & Wear NHS Trusts	Health Profiler
Northumbria University	Data Analyst
Northumbrian Water	Senior Manager
Primary Care Trust	Medical
Primary Care Trust	Non medical
Primary Care Trust	Medical
Primary Care Trust	Non medical
Public Health Observatory	Senior Manager
Public Health Consultancy	Senior Manager
Strategic Health Authority	Senior Manager
Sure Start	Manager

4.7 Ethical considerations

There were a number of pertinent ethical considerations involved in the study. First, in view of GIS technologies there are certain political sensitivities to consider regarding data display. Geographical information systems were used to display potentially contentious data on environmental lead contamination. It is, therefore, critical that these sensitivities were acknowledged in the interviews. The preliminary mapping phase of the study examined publicly available data, which did not necessitate the study to be presented for ethical review at that stage. The study underwent in house ethical review to access data held by the Regional Maternity Survey Office (RMSO). Identifiers were removed and postcode data on birth weight were translated to XY grid references before onsite abstraction from the RMSO database took place.

[8] Microphone recording equipment failed therefore data were collected as verbatim notes rather than a transcribed audio recording.

At the time, the in-depth procedures required to interview a small number of NHS senior service managers seemed unnecessarily involved, almost prohibitive to the research process. The study had to undergo the same procedures and intense scrutiny as one involving vulnerable groups or patients. It could be argued that the ethical review process, which was protective of the participants ignored the safety and rights of the researcher who was probably the more vulnerable party in the power relations. The experience of peer review by first the University Ethics Committee and then the Northumberland Research Ethics Committee did, however, serve as a positive, reflective and focusing experience.

The central ethical issue of concern in the study was ensuring anonymity during recruitment, interview discussions and when reporting the study findings in research outputs and presentations to the Lead Task Force group. Anonymity and confidentiality are concerns when interviewing elites as they can easily be identified by their position and job title (Gillham, 2000). It was critical to exercise caution and care when approaching potential interview candidates and to minimise the risk of identification in research outputs by selecting quotes which – through the type of vocabulary or 'buzz words' used – were not easily traced back to a particular individual. By increasing the geographical location for sampling, from the metropolitan district of Newcastle to the region of the North East of England, the risk of identifying respondents by their position within a particular organisation was reduced.

Despite introducing a number of measures to reduce the risk of identification, it was important to discuss the issue of anonymity when approaching potential interviewees and before obtaining informed consent. Furthermore, it was necessary to articulate these concerns in the participant information sheet to make sure that participants were properly informed and aware of the risk of identification in the study. Participants were referred to as a 'key decision maker' from his or her particular organization and it was communicated in the information sheet that anonymity could not be guaranteed. During the interviews it was important to establish a rapport with the participants to enable them to trust the researcher. It was made explicit in the information sheet and correspondence with participants that the aim of the interviews was not to judge the interviewee's competency with GIS nor was it to ask about accountability issues in terms of environmental contamination. These ideas

were reinforced during the interviews by exercising caution regarding the type of vocabulary used. Interview recordings were transcribed and edited to ensure confidentiality and anonymity.

4.8 Conclusion

Complexity theory has been used in this chapter to make sense of the challenges and limitations of the case study approach. The case example of childhood lead exposure presents a means of drawing together the themes of interest: public health decision-making and the use of evidence in decision-making pathways. Childhood lead exposure was chosen as it is a relevant, multi-faceted public health issue, which involves decision-making processes and is well suited to exploration using GIS. An approach to data analysis based on the constructs of complexity discourse now follows.

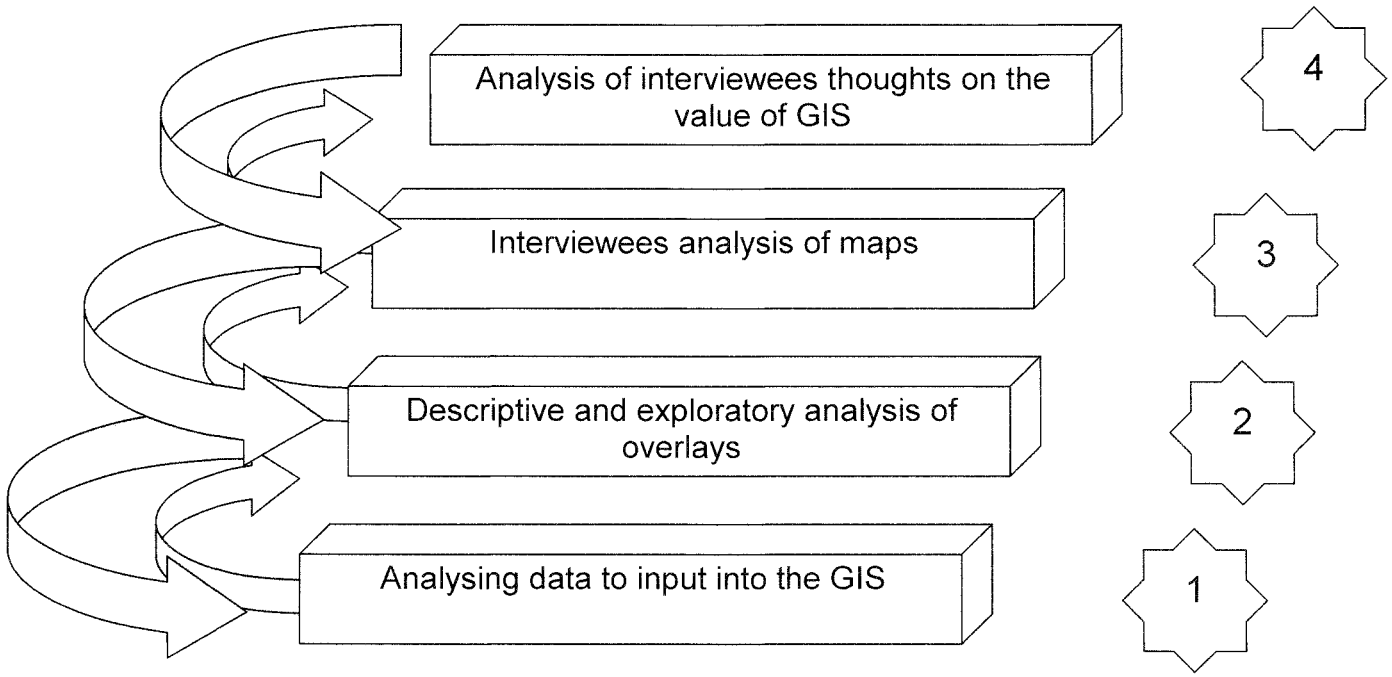
"Complexity offers the possibility of an engaged science not founded in pride, in the assertion of an absolute knowledge…but rather in a humility about the complexity of the world coupled with a hopeful belief in the potential of human beings for doing something about it" (Byrne, 1998, p.45).

Chapter 5: Data Analysis

5.1 Introduction

The data analysis chapter serves to lay out the approach to analysis of the study findings while providing justification for the decisions taken. Approaches to establishing validity and reliability in both the mapping exercise and in qualitative data collection and analysis are explained. Interim analysis (Miles and Huberman, 1994) was undertaken during data collection, which was fed back into the interview schedule. Analysis adopted a similar approach to Pope, Ziebland and Mays (2000b) and Swallow, Newton and Van Lottum (2003) incorporating stages of data familiarisation, theme development, indexing and coding, charting, mapping and interpretation. Following the complexity paradigm much understanding emerged from examination and reflection on the inter-relationships between each of the layers of analysis (as shown in figure 5.1). The constructs of emergence, attractors, uncertainty and paradox were used as guiding and reflecting principles in the analytical approach.

Figure 5.1: Layers of analysis



5.2 Structure of the analysis

Twenty-two interviews were conducted with twenty three participants in the North East of England, mostly within the Tyne and Wear conurbation. Individuals and their organisation were coded for anonymity (see table 5.1

below). Interviews lasted between twenty minutes and two hours but the average duration was sixty eight minutes (see table 5.1). Face to face interviews were conducted with participants at a location of their choosing, usually their place of work. For geographical reasons, one telephone interview was undertaken and a joint interview was conducted at another participant's request. With only one exception, the interviews were audio-recorded and later transcribed verbatim. Non-verbal cues were recorded after the interviews, in the contact summary sheets, as the researcher felt that these details could illuminate the audio data. To improve readability basic punctuation (question marks, full stops and commas) was added to the transcripts before they were analysed. For a sample of excerpts from the interview transcripts see appendix VII.

Table 5.1: The Interviewees

Agency	Gender	Interview Type	Duration (mins)	Role	GIS experience
A	♂		45	Environment	Knowledge
B	♀		97	Environment	Experience
C	♀		22	Environment	Applied Experience
D	♂		110	Health Data	Applied Experience
E	♀	Joint	72	Health	Knowledge
F	♂	Joint	72	Environment	Experience
G	♂		57	Data	Applied Experience
H	♀		80	Health	Knowledge
I	♂		55	Health	Applied Experience
J	♀		49	Community	Knowledge
K	♀		86	Health	Knowledge
L	♂		51	Health	Experience
M	♀		64	Health	Experience
N	♂		101	Health	Experience
O	♀		46	Health	Knowledge
P	♀		68	Health	Knowledge
Q	♀	Phone	27	Health	Knowledge
R	♂		69	Community	Experience
S	♂		44	Health	Knowledge
T	♀		58	Data	Applied Experience
U	♂		53	Academia	Experience
V	♂		70	Community	Applied Experience
W	♀		95	Health	Knowledge

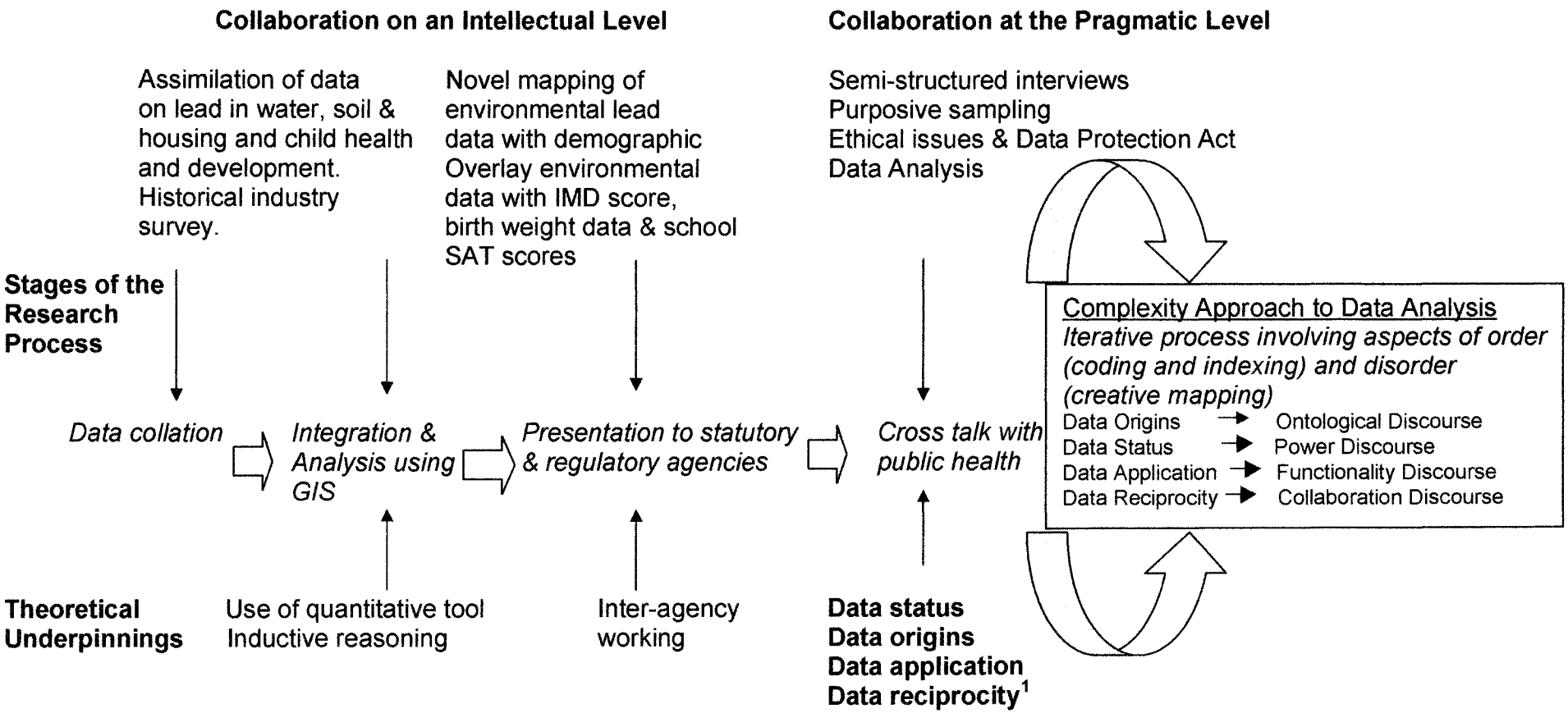
In total 11 male and 12 female participants were recruited to the study. Prior to the interviews each participant was sent a copy of the mapping report to

introduce the concept of mapping and to stimulate critical debate. The interview transcripts together with field notes recorded in contact summary sheets (refer to appendix VIII) and researcher reflections, captured in a research diary (see appendix IX) were analysed. In conjunction with the ethos of complexity discourse respondents were not categorised or labelled explicitly as protagonists or antagonists with respect to their thoughts and views on GIS mapping. Data collection continued with snowball sampling until all major themes were saturated and no new themes emerged from the interviews. Despite planning to conduct eight interviews, the sample reached twenty three participants from twenty two agencies involved either directly or indirectly in public health.

5.3 Reintroducing the conceptual framework for analysis

The three central constructs of: data origins, data status, and data application were used to shape data collection and analysis (see figure 5.2). The iterative process of thematic analysis saw the emergence of a fourth construct: data sharing/data alliances, which is collectively summarised as data reciprocity. These constructs were used together with the notions of attractors, paradox and emergence, all central to complex systems thinking, to guide the analytical process. The themes are demonstrated, in Chapter 7, using sample quotations from the primary data. Many of the quotations included are lengthy as from a complexity perspective it was important not to lose context and meaning, which may have occurred if quotations had been extracted from or shortened.

Figure 5.2: A complexity approach to analysis: the importance of inter-connections and linkages



[1] The theme of data reciprocity emerged through the process of thematic analysis and is therefore introduced to the theoretical framework

5.4 The process of analysis

As Bryman and Burgess (1994) recognise, the process of qualitative analysis is not straightforward due to the volume and textured nature of the data. Unlike quantitative research, there are no standard ways of going about analysis and rigid adherence to prescriptive frameworks or checklists could undermine the meaningfulness of qualitative data (Barbour, 2001). Smith (1996) endorses the view that qualitative analysis is a creative process, an art, which relies on a close relationship between data, researcher and respondent. Accordingly many researchers advocate the 'do what fits' approach instead of strictly adhering to a rigid framework for analysis. This does not, however, circumvent the requirement for robust and transparent methods to ensure trustworthiness in the conceptual findings.

In grounded theory approaches, the process of theory building is hallmarked by the notion that "*data collection and analysis are interwoven procedures*" and theory building should be borne in mind throughout the process from study design through to data collection, analysis and reporting (Strauss and Corbin, 1998, p.281). Although this study is not directly applying the principles of grounded theory *per se*, the researcher did not view the phases of data collection and analysis as distinct linear stages. Instead, through the use of complexity theory, the study adopted a dynamic and iterative approach to data collection and thematic analysis, where interviews were conducted and data managed and analysed to identify emerging themes, which could then be explored in later interviews. In this way, preliminary analysis informed the schedule for subsequent interviews and themes could then evolve in an organic process rather than in a pressurised and rigid environment, which would not have been in keeping with the qualitative research paradigm and the concept of emergence. Pope, Ziebland and Mays (2000a) also suggest that by undertaking analysis continuously, whilst in the field, 'deviant' or negative cases can be identified that may negate any initial hypotheses. By adopting a reflexive approach, understanding emerged as the researcher's relationship with the data developed (Lessard, 2007).

Forest and Meunier (2005) define thematic analysis as the identification and patterning of key ideas, constructs or themes in a text and suggest a 'data mining' approach to analysis using computer software. Welsh (2002) advocates the use of computer assisted qualitative analysis to understand and explore the

data, whilst at the same time providing a clear and transparent audit trail. In contrast, Pope, Ziebland and Mays (2000a, p.82) caution that the use of qualitative data analysis packages, such as Nudist or NVivo should not be seen as technique to guarantee "*rigorous and systematic analysis*". Rather, software packages are tools to assist in the process of analysis and ensuring rigour and the quality of the analyses is dependent on the "*skill, vision and integrity*" of the researcher (Pope, Ziebland and Mays, 2000a, p.87). Moreover, Swallow, Newton and Van Lottum (2003) recognise the difficulties associated with analytic software packages in terms of investing resources to acquire the software and time to learning the necessary skills.

The interview tapes were coded and analysed using Microsoft Word (La Pelle, 2004) and Microsoft Excel (Swallow, Newton and Van Lottum, 2003), as the software for qualitative analysis such as Nu*Dist or NVivo was not available through the University. An attractive feature of qualitative studies is the flexibility that the research design allows for accommodating what some people refer to as 'best fit'. Accordingly, Swallow, Newton and Van Lottum's schema (2003) for analysis using Microsoft Excel was adapted and used to fit in with 'what felt best' to the researcher alongside approaches endorsed by Miles and Huberman (1994) and Pope Ziebland and Mays (2000b). The time, energy and expense involved in learning to use another software package and perhaps a certain frustration and discomfort with new technologies precluded the researcher buying and using the NVivo software herself.

5.5 Framework for thematic analysis

Morse (1994) suggests four cognitive processes involved in qualitative analysis, which include: (i) comprehending the data; (ii) synthesising a picture of the data which describes linkages and relationships between each of the factors involved; (iii) theorising about the data and (iv) re-conceptualising the new knowledge in context. Similarly, Pope, Ziebland and Mays (2000b) set out a schema for thematic analysis involving five stages as shown in figure 5.3. However, rather than being a linear process an iterative approach was adopted whereby the initial stages of re-reading the raw data and familiarisation were returned to as themes began to emerge. Based on this framework the process involved multiple, inter-related stages, which were repeated, reflected upon and returned to at different times during the analytic process (see figure 5.4). An

additional stage, 'writing up', was included in the framework as ideas developed further and discourses emerged through the process of writing.

Figure 5.3: Stages of thematic analysis (adapted from Pope, Ziebland and Mays [2000b])

1. Familiarisation with data
2. Identifying a thematic framework – note all central issues, concepts and themes. Label sections of the text in manageable chunks.
3. Indexing of themes and categories to produce "fuzzy categories" by applying thematic framework. Annotate with numerical codes.
4. Charting – paper systems to develop deep understanding, abstraction and synthesis.
5. Mapping and Interpretation

Drawing on the influence of the complexity model, data analysis was conceptualised as an iterative process with multiple, inter-related parts, which were repeated until understanding emerged. The process began with data familiarisation which included listening to the audio tapes, transcribing the interview data, reading and re-reading the interview transcripts and breaking down the data into manageable chunks. Mason (1994) emphasises the difference between managing the data (breaking it down into meaningful chunks to be digested further) and actually undertaking the analysis. Mason advocates an approach whereby two sets of analytical categories, descriptive and conceptual, are generated to make sense of the data.

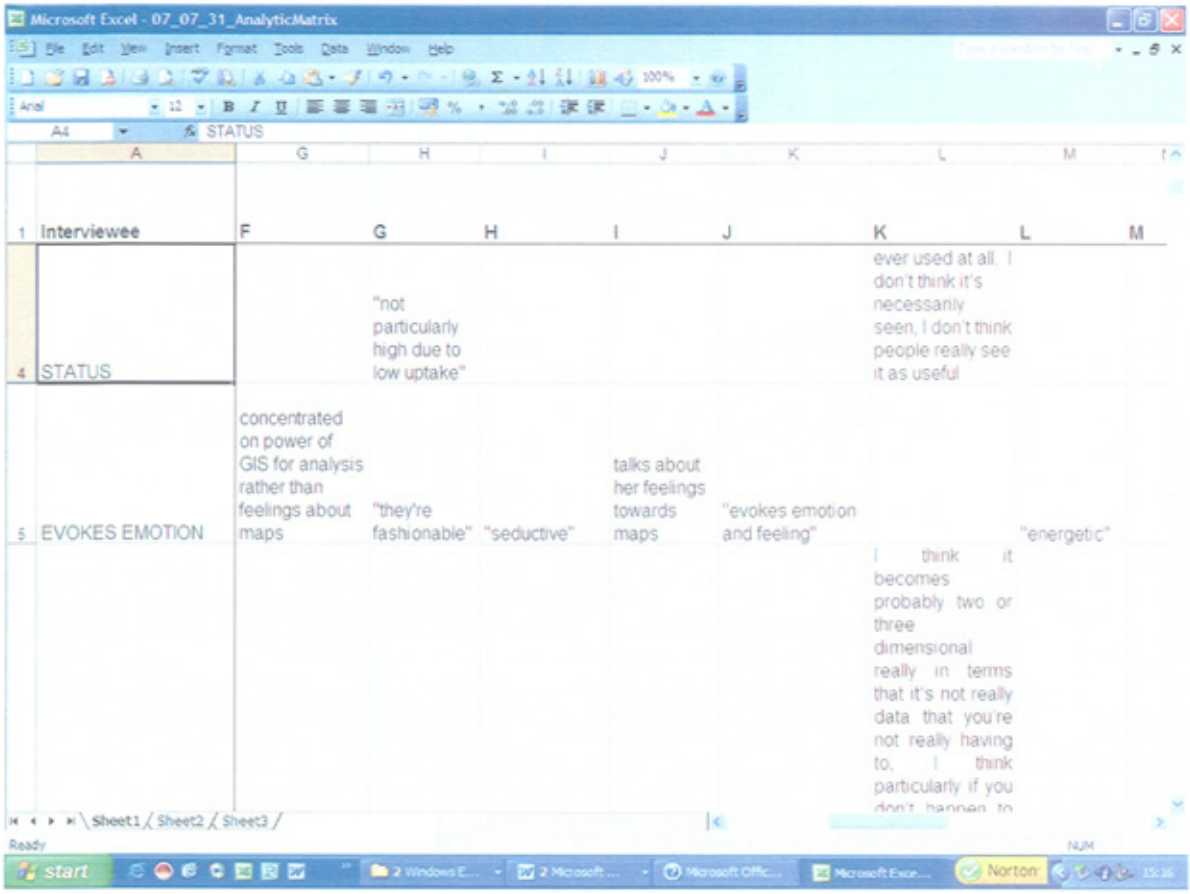
The thematic framework for analysis was partly pre-determined and based around the core interview themes developed from the study aims and objectives (data origins, data status, data power and data reciprocity). However this basic framework evolved to include themes emerging from the interviews. The use of partly pre-determined themes to drive analysis reconciles the notion of bridging the gap between order and disorder in complexity theory. Themes and sub-themes were identified in initial interviews and explored and 'drilled into' in further discussions. According to Ryan and Bernard (2003) a number of techniques can be used to generate themes and codes as set out in table 5.2 below. These methods are based on ideas proposed by Strauss and Corbin (1998) and are rooted in the grounded theory approach. Although this study did not employ grounded theory, the ideas were useful to guide the coding process.

Table 5.2 Techniques to generate themes and codes (adapted from Ryan and Bernard, 2003; Gibbs and Taylor, 2005).

Technique
Word Repetitions
Key words in context
Compare and contrast
Social Science Queries
Searching for missing information
Metaphors and analogies
Transitions
Connectors
Unmarked text
Pawing/Handling
Cutting and sorting

Swallow, Newton and Van Lottum's (2003) approach to charting involved the use of Excel to display and sort quotations representative of key themes (see example in figure 5.4). Microsoft Excel enabled searches for patterns in the data and identification of deviant or negative cases.

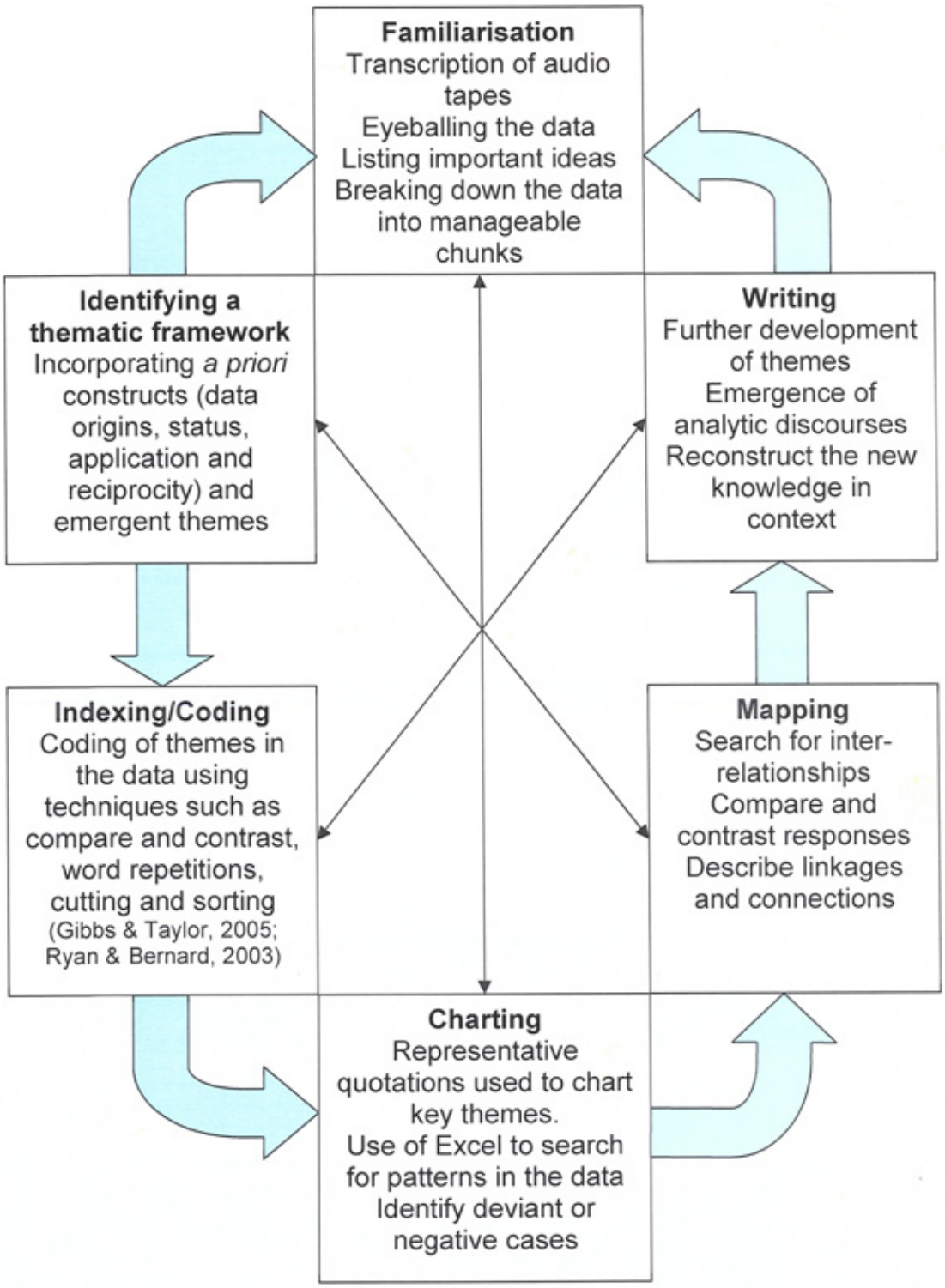
Figure 5.4: An example to demonstrate the use of Microsoft Excel for charting



Once the stages of indexing and charting had been considered a creative approach to mapping and data interpretation was adopted involving 'post it' notes, colour coding and contour mapping. Based on Buzan and Buzan's concept of mind mapping (2003, p.87), the study question was "*crystallised*" centrally and themes were presented radiating in an "*interconnected nodal structure*". The graphic process was adapted to incorporate contour lines to demonstrate important themes in proximal lines and connected sub-themes in more distal contour lines. The idea behind this stage of analysis parallels the thesis's concern with the use of mapping (GIS or otherwise) in public health.

Bowling (1997) makes the observation that research is not value free and the researcher brings his or her own set of beliefs, which shape the interpretation of results and the development of theory. Knowledge is produced through dialogue between the interviewer and interviewee and is often based on the experiences of the interviewee and his or her interpretations of these experiences rather than on accurate depictions of reality (Puntambekar, 2006). Themes emerge from the data through a process of interpretation so it follows that meanings ascribed to the data by different researchers may not always be congruent. Understandings are shaped by lived experience and pre-existing knowledge. It was critical, therefore, that the researcher made any biases explicit from the outset (Gilham, 2000). The relationship developed between the researcher and respondent also influences the information shared in the interview situation. The position of the interviewer as a young female researcher is likely to have affected this dynamic to some extent (see the Epilogue).

Figure 5.5: An iterative and cyclical approach to thematic analysis (incorporating ideas and stages from Morse, 1994; Pope, Ziebland and Mays, 2000b; Swallow, 2003)



5.6 The use of the complexity model in analysis

Complexity theory was employed to frame the analytical approach. The constructs of emergence, attractors, uncertainty and paradox were used as reflecting principles. The analytic framework incorporated a number of pre-determined constructs but enabled themes to develop through data familiarisation, coding, charting and mapping. In terms of complexity dialogue this approach was akin to bridging the elements of order and disorder within the study. Byrne (1997) endorses the whole systems approach to data analysis whereby the thread of understanding should not be lost by focussing on inconsequential detail. Complexity models of data analysis focus on understanding inter-connectedness and the relationships between elements rather than simply understanding the elements themselves.

In terms of data analysis understanding and interpretation is an emergent property. In this sense, the attractors (referred to by Plesk and Greenhalgh [2001] as the internalised rules) are the methods to establish validity and reliability. Elements of paradox were noted in examination of 'deviant' cases. One such example was uncovered in relation to the use of GIS being at odds with collaborative public health practice (see section 7.7.1). This view demonstrated the inherent paradox between GIS as a technocratic device and maps as democratic vehicles for communication purposes.

5.7 Establishing validity and reliability in the case study approach

5.7.1 Validity and reliability in the mapping phase

Yin (1993, p39-40) emphasises the need to establish internal, external and construct validity in case study research. Construct validity refers to the link between measurement and theory and the extent to which a measurement relates to the theoretical construct being examined (Yin, 1993, p.39; Ward and Holman, 2001, p.50). Content validity is defined as how far a measurement considers all of the possible dimensions of the theoretical construct (Ward and Holman, 2001, p.50).

Internal validity considers the extent to which inferences made in the study are actually true within the study population. External validity or generalisability refers to how far the results obtained in the study can be generalised to other populations. Yin (2003) advocates the use of specified units of analysis together with the development of alternative theories which he

terms 'rivals' to achieve internal validity. Here both the suggestion that GIS maps can facilitate evidence-based decision-making and the hypothesis that GIS and map outputs are not valued in public health practice are tested. In terms of external validity it is difficult to generalise the results to other organisational contexts with different remits, goals and priorities. There are, however, several organisations that share similar working philosophies and serve communities with comparable demographic profiles. The findings gathered here could, therefore, assist in the design of similar studies into the use and value of GIS outside the public health domain.

Reliability is a measure of how stable the research methods are to reproduce the same results in further studies (Ward and Holman, 2001, p.50). Yin (1993, p.40) advises the use of formal protocols and a case study database to ensure reliability. The inherent attributes of GIS in data storage, management and manipulation help to achieve reliability in this context.

5.7.2 Validity and reliability in qualitative data collection and analysis

The constructs of validity and reliability are central to establishing trustworthiness and credibility in the data. Validity refers to whether the results are about what they seem to be about and reliability is a measure of the consistency of results (Robson, 2003, p.170). The terms 'validity' and 'reliability' tend to refer to the quantitative research paradigm and the notions of trustworthiness and dependability have been adopted with analogous meanings in the qualitative literature.

Dixon-Woods and colleagues (2004) highlight the ambiguity surrounding the development of criteria to measure quality in qualitative research. There are conflicting viewpoints as a consequence of the multiplicity of research philosophies associated with qualitative work. On one hand computer software packages such as NVivo are endorsed as tools to generate robust analyses but others prefer a more flexible and creative approach to understanding and interpreting data (Dixon-Woods *et al.* 2004). Barbour (2001) warns that qualitative research should not try to conform to the standards of quantitative studies by being overly prescriptive. It is crucial, however, to make the research process transparent by detailing the audit trail to support the process through which themes have emerged.

Figure 5.6: Techniques to enhance reliability and validity in case study research

(Adapted from Riege (2003)

Measures to establish construct validity (confirmability)

1) Established a clear audit trail with field notes captured in contact summary sheets and the execution of a research diary to monitor, track and reflect upon the data collection process (see appendices VIII and IX respectively).

2) In the collaborative spirit incorporate respondent review of research outputs (see appendix XI).

Measures to establish internal validity (credibility)

1) Make researcher biases and theoretical orientation explicit (see Complexity and Public Health, chapter 3 and Epilogue).

2) Peer debriefing (Gilham, 2000) in Postgraduate Student Group meetings.

3) Supervisor checks for congruence between codes and raw data.

Measures to increase external validity (trustworthiness)

1) Clear definition of the research boundaries during the design phase to assist in achieving analytical generalisations.

2) Adhere to a specific framework for coding and analysis (Miles and Huberman 1994; Pope, Ziebland and Mays, 2000b; Swallow, Newton and Van Lottum, 2003).

3) Compare evidence with the existing literature.

4) The use of a sample of predetermined questions (see appendix V).

Measures to establish reliability (dependability)

1) Case study refinement during research design phase, with one pilot interview being conducted to improve the interview schedule and test the audio equipment prior to commencing data collection.

2) Development and maintenance of a case study database (see appendix VI) to provide a mechanism for the organisation and documentation of data collected (Yin, 2003).

3) Recording of audio data mechanically with digital equipment.

4) Audit trail (documentation of audit trail with research diary, study database and contact summary sheets).

Using a framework documented by Riege (2003) attempts were made to establish rigour as shown in figure 5.6. Some of the techniques cited are methods specific to the qualitative research tradition, whereas others are inherent in good case study practice. In the study findings, raw data are presented along with the researcher's interpretation to allow the reader to understand how key themes have emerged from the data. Sanger (1994) argues against the rigidity and conservatism of traditional techniques of analysis and endorses reflexivity as an integral part of data analysis. Following Sanger's approach a reflexive research diary was used to chart progress, to generate and store ideas and to identify potential areas of bias in the methodological and analytical strategies. Other important methods of establishing credible and trustworthy findings included documentation of a clear, open and transparent audit trail and presentation of interim findings and analytical approach (Gilham, 2000) at postgraduate student group meetings and regional conferences.

5.8 Conclusion

This chapter has presented an approach to data analysis in keeping with the complexity paradigm. The approach incorporated analytic stages defined by Pope, Ziebland and Mays (2000b) as familiarisation, thematic framework development, coding/indexing, charting and mapping. In addition, writing-up was included as an integral part of analysis. Analysis was conceptualised as a cyclical and iterative process where concepts and ideas emerged at the zone of inter-connection between phases. The flexibility of this approach enabled creativity. The emergent themes were grouped into four discourses presented in chapter 7. In the following chapter the process of map making is reflected upon and a discussion of how participants interacted and perceived the mapping report is presented.

Preface to the findings chapters

The findings of the mapping and interview phases of the study are laid out in chapters 6 and 7. To begin, Chapter 6 describes the results of the GIS mapping exercise, together with a discussion of how decision-makers reacted to the mapping report disseminated to participants prior to interview. The mapping report (see Appendix I, volume II) was used to engage participants in discussion about the value of GIS in public health practice. The chapter commences with a commentary on the data-related decision pathways involved in the process of map making. A range of maps were produced some of which demonstrated the benefits of GIS and others the limitations and potential drawbacks of maps as evidence. The reactions of participants to the mapping report are laid out and unpicked to follow up the debate opened by the stimulus GIS material. The role of complexity theory in guiding analysis is outlined and the complex nature of 'the case' embedded within the study is explained. Finally, the key themes from the interview phase relating to values and meanings associated with the maps are translated into practical considerations in the real world of public health.

In Chapter 7 the themes emerging from the interviews on the value of GIS technologies and the meaning of maps as evidence in decision-making are described and discussed. Discourses around ontology, power, functionality and collaboration are introduced and considered in terms of the complexity framework. While the principle function of chapters 6 and 7 is to describe the study findings, the central themes for discussion are signposted to be explored in depth in chapter 8, the Discussion.

Quotes to evidence the salient themes are cited in italics and referenced using a transcript code. Codes incorporate an alphabetical letter for the organisation represented, followed by the page and line number from which the excerpt was taken. For example, the code 'B, 8/471' refers to a quote made by a public health decision-maker working for Organisation B. The excerpt is taken from page 8 of the interview transcript, and begins on line 471. Readers are referred to table 5.1 where further information regarding the agencies involved is laid out along with details relating to interview duration, gender of interviewee and type of interview (telephone versus face to face and individual versus group interview).

"We envision information in order to reason about, communicate, document and preserve that knowledge"
(Tufte, 1990, p.33).

Chapter 6: GIS mapping of data relating to childhood lead exposure

6.1 Introduction

Chapter 6 presents the findings of the mapping exercise, which involved the production of GIS maps to integrate multiple and disparate data on a current and topical public health concern. GIS was used in a descriptive and exploratory capacity to examine the issue of childhood lead exposure. The first section (6.2) will concentrate on the mapping exercise, the processes through which the maps were made and the decisions undertaken in production of the mapping report. Section 6.3 will then move on to how the mapping report was received by interviewees to set the scene for discussion of the thematic findings in chapter 7.

6.2 The mapping exercise

6.2.1 The process of map making

The objectives of the mapping phase were:

(i) to explore the GIS tool box;

(ii) to understand the benefits (and limitations) of GIS software in the collation, integration and presentation of data;

(iii) gain a first hand understanding of the strengths and weaknesses of maps as strands of evidence for public health decision-making;

(iv) to produce a mapping report to be used as stimulus material in the interview discussions.

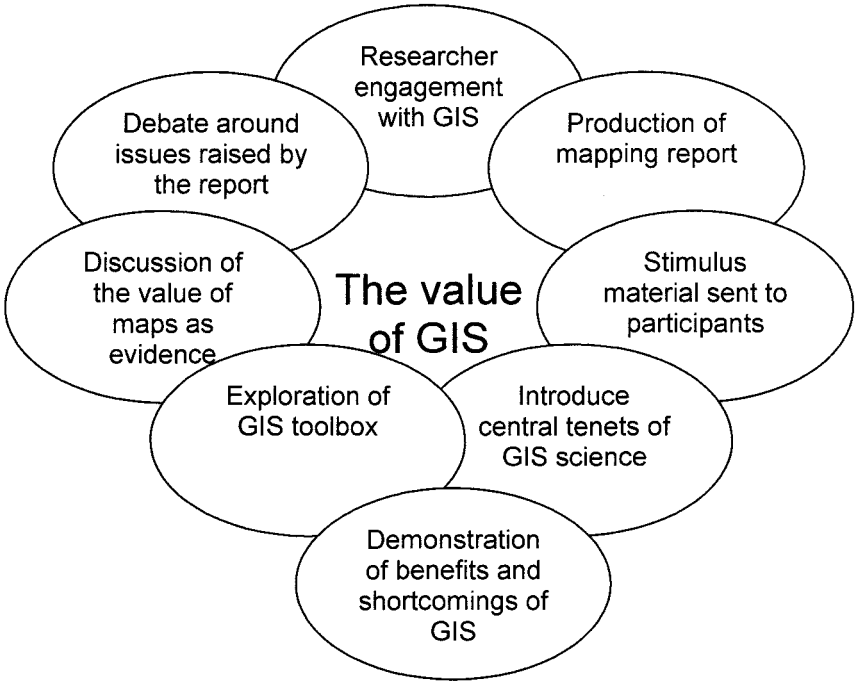
Weber (1864-1920) suggested that to research a subject the researcher should 'know' the phenomenon themselves to gain empathy and a true, in depth understanding of what that phenomenon 'means' to the actor (Cohen, 2000). Weber termed this construct 'Verstehen' or 'interpretive understanding' (Bilton *et al.* 1981). The GIS mapping exercise was designed to enable this opportunity – to explore, interpret and understand in an attempt to gain insight and knowledge of the phenomenon before engaging with decision-makers in the interview phase.

Weber distinguished between statements of facts and statements of values in that to understand the facts of a phenomenon does not involve a value estimation. Likewise, a stance on the value of a phenomenon does not qualify knowledge on the subject. Weber's views on values are complex (Bilton *et al.*,

1981). While he endorsed a value free approach to knowledge assimilation he recognised that ethical and political responsibilities would impact on how that knowledge was used (Bilton *et al.*, 1981). During the interviewing phase the issue of neutrality is raised as to whether the researcher, with this first hand knowledge and experience of the phenomenon under investigation, can act appropriately so as not to bias, coerce or influence participants with her existing knowledge. The relations between knowledge and values are necessarily complex they are inextricably linked to experience, culture, history and context (Parker, 1999) by non-linear and unpredictable pathways.

The report (see appendix I, volume II) was designed to illustrate the concepts of GIS mapping whilst also demonstrating some of the benefits and shortcomings of GIS map representations as evidence in decision-making processes. For some, the report merely acted as a reminder of how GIS can be employed to draw together multiple strands of data regarding a complex public health issue, whereas for others the report demonstrated the key functions of the GIS toolbox (such as overlay analysis) and introduced possible GIS applications in public health. The importance of the mapping report, its production and dissemination to participants, the use of the report to engage with respondents, to reinforce the central principles of GIS science, and to illustrate the advantages and limitations GIS toolbox are drawn together and illustrated in the project life cycle laid out in figure 6.1 below.

Figure 6.1: The study lifecycle



The bubble described as 'Researcher engagement with GIS' is far more complex than it appears in the above diagram. Several contingent and relational activities were undertaken including: identifying sources of relevant data; negotiating access to datasets; securing ethical or gatekeeper approval and systematically critiquing each dataset before selecting which should be included in the mapping exercise.

6.2.2 Mapping elements of childhood lead exposure in Newcastle upon Tyne

The mapping report examined the issue of childhood lead exposure, a public health concern that requires timely investigation for the following reasons:

- Contemporary research in Australia and the United States has associated the heavy metal lead (Pb) with cognitive impairment and behavioural problems in children (Canfield *et al.,* 2003; Tong *et al.*, 1996).
- Exposure and uptake are not distributed equally throughout different socio-economic groups and children with pre-existing nutritional deficiencies living in areas with multiple sources of lead contamination tend to be disproportionately affected (Centers for Disease Control and Prevention, 2000).
- In the UK there is a paucity of recent epidemiological studies on the risk of lead to children. Furthermore, there is little evidence available to demonstrate the unequal distribution of lead geographically and throughout the social strata.

Thus, as a secondary objective, the mapping report was designed to provide some preliminary descriptive data on the distribution of environmental lead, from a range of disparate sources, throughout Newcastle upon Tyne. Map overlays were produced using the best data available and sometimes (as it will be discussed further) these data were not suited to answer the questions posed. It should be made clear that the report was not intended as an analytical piece of work to support inferences and to make conclusions about the issue of childhood lead exposure in Newcastle. Instead the aim was to provide data in a GIS format on a real public health issue for interviewees to explore, examine and assess. This way the issue of GIS as a method for presenting evidence for decision-making could be examined and unpicked.

6.2.3 Evolution of the mapping exercise

The original aim of the mapping exercise was to produce a timely profile or 'picture' incorporating multiple aspects of potential childhood lead exposure in the district of Newcastle upon Tyne. Most researchers at some stage discover that grandiose aims and objectives have to be amended, adapted and sometimes even curtailed to fit with the actualities of real world research. In this study the intention to produce an aggregate map integrating lead levels from soil, water and housing in an overall score was overly ambitious and unrealistic, principally due to limitations associated with the secondary datasets.

First, there was a paucity of secondary data available on the issue of lead contamination. The data that were available tended to be out of date (soil dataset A, depicted in figures 6.4, 6.6 and 6.9) or in some cases inconsistent or of dubious quality (historical data on infant mortality rate, see figure 6.3). Data that filled the criteria of timeliness, reliability and validity were sometimes incomplete or had been collected over a smaller or different geographical area (soil dataset B, refer to figure 6.8). In other cases it was clear that the data were inappropriate for use because the studies through which they had been collected addressed different research questions (water lead sampling, see figure 6.7). The caveats associated with each of the datasets accessed are described in table 6.1.

The links with complexity theory are clear: the data accessed were not straightforward, the information was incomplete, lacking consistency, unreliable or out of date. As discussed in chapter 3, however, just because something is unclear, problematic and complicated does not mean that it should be ignored. With these considerations in mind the mapping phase took on a more descriptive and exploratory focus where the GIS outputs provided a way of representing existing data in a spatial format. The maps provided a means of looking at the data using spatial pictures or 'snapshots' rather than graphs, tables or statistics, which enabled an exploration of how public health practitioners valued maps as strands of evidence and GIS as a tool for decision-making.

6.2.4 Decisions and dilemmas in the process of map making

A form of analysis was undertaken when decisions were made regarding which datasets to include and which to omit in the mapping exercise. It was felt that the limitations of the data sets themselves actually precluded more in depth geostatistical analyses. The value of statistical analyses is undisputed. In fact several decision-makers interviewed felt that the power of GIS was in its analytical capacities. In this study, however, analysis of the datasets determined that the data were just not robust enough to enable geostatistical modelling techniques such as krigging (McDonnell & Kemp 1995).

The process was akin to meta-analysis or systematic review in that each dataset was thoroughly and systematically critiqued in terms of timeliness/currency; completeness; consistency; reliability; validity; accuracy; robustness and trustworthiness. The notions of trustworthiness and rigour, which are associated more commonly with the qualitative paradigm, were also included in the framework for critique as they seemed to relate more to some of the datasets included than the positivistic notions of reliability and validity. Complexity theory was drawn upon to understand how maps can be used to examine contingent relationships (Byrne, 1998) and to make sense of elements of conflict, paradox and tension (Plesk and Greenhalgh, 2001).

The characteristics and limitations of the datasets collated and critiqued are summarised in the table 6.1 below. In relation to the case issue, childhood lead exposure, validity was a particularly salient concern as there are no existing secondary datasets on blood or bone lead levels in children to use as a reliable and valid indicator of body burden. While blood lead sampling is permitted in the USA and used as a measure of recent exposure to environmental lead, robust ethical arrangements preclude such testing in the UK. Timeliness was a limiting factor that prohibited the use of a number of data sources. Many of the datasets reviewed were out of date, for example the soil sampling data were sampled some twenty years earlier (Aspinall *et al.* 1988, see figure 6.4, 6.6 and 6.9). Despite lead being a persistent heavy metal with an extensive half life in soil, data collected in the 1980s are unlikely to demonstrate a true representation of lead levels in the environment today. Changes in land use, soil structure and weather conditions may have affected soil lead burden. A number of the datasets were incomplete, such as the historical data on infant mortality (figure 6.3). The relevance of this dataset to

the research issue could also be called into question. An example of data (in)consistency involves Northumbrian Water's sampling strategy (see figure 6.7) whereby if elevated lead levels are recorded follow-up readings are taken but not made publicly available and so could not be included in the mapping. The framework for reviewing and appraising each dataset prior to inclusion in the map outputs was described in greater detail in figure 4.3.

Bhopal (2002) describes a number of fallacies associated with the interpretation of epidemiological data. These ideas are equally fitting in the context of GIS mapping where they resonate with some of the issues, problems and tensions encountered during the mapping exercise. Bhopal (2002) recognises the difficulties of extracting the 'correct' interpretation of the data. There is a risk that the individual producing the data may have consciously or subconsciously manipulated the information to communicate a particular message. Furthermore, Bhopal (2002) acknowledges the tendency and preference to base interpretations on practice and personal experience, this was something to be considered when the report was taken to decision-makers.

Another interesting point raised by Bhopal, which remained pertinent throughout the mapping experience, was the idea that it is not possible to pool together a series of weak evidence to turn it into something stronger. During the interviews it was interesting to observe how decision-makers engaged with the evidence and whether or not they felt there was insufficient information on which to base robust decisions. It would be impracticable and unrealistic, however, for practitioners to dismiss GIS simply on the basis of the absence of robust datasets. To use a commonly used adage it would be like 'chucking the baby out with the bath water'.

Dataset	Source & Description	Relevance	Currency	Validity	Reliability	Consistency	Completeness	Trustworthy	Coverage	Appropriateness	Inclusion	Limitations
Water Lead Sampling	Random Sampling by population density	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	The data provided were those that were publicly available. There was no way of accessing data from houses which had recorded elevated lead levels and follow up.
Soil Lead Sampling 1	Aspinall *et al.* (1988), 1 km grid sampling framework	Y	N	Y	Y	Y	N	Y	N	Y	Y	Timeliness was the main issue but also the use of a crude sampling grid limited the usefulness of the dataset
Soil Lead Sampling 2	Byker Incinerator Study (2003)	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Only covered a defined radius from the incinerator so data were limited spatially.
Index of Multiple Deprivation	Office of the Deputy Prime Minister	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	By defined geographical unit – SOA only. There may be pockets of affluence or deprivation within SOAs.
Historical Industry	Ordnance Survey Maps for the following epochs: 1856, 1898, 1910, 1930s, 1960-1980	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Point dataset. No detail of the land mass occupied by the industry or the number of people working
House Age	Shapefiles produced from historical map data and validated using street by street surveys	Y	N	N	N	N	N	N	Y	N	N	No accurate record of modernisation. A proxy indicator of house age was made by consulting historical maps along with validation using street by street surveys. Incomplete.
Birth Weight	Data collected from RMSO	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Difficulties with the complexity of birth weight and the number of mediating variables and potential confounders involved. Overlays may infer spurious associations.
SAT Score	Collated from publicly available SAT data	Y	.Y	Y	N	Y	Y	Y	Y	N	Y	Crude indicator with questionable reliability. Difficulties associated with prompting erroneous conclusions. Again the complexity of the putative relationship is self-evident.
Road Network Data	ONS data; LA data	N	Y	Y	Y	Y	Y	Y	Y	N	N	Not very useful, lead phased out of petrol.
Historical Infant Mortality Data	Historical MOH Reports using 1800s boundaries (Digimap)	N	N	Y	N	N	N	Y	N	N	N	Data were incomplete and deemed not to be relevant to the question of interest.

Key: Y = Yes; N=No

Table 6.1: Limitations of the secondary datasets reviewed for inclusion in the GIS

6.2.5 The mechanics of the GIS exercise

For a novice GIS user the process of map making was time consuming, challenging and necessitated much anxiety and trial and error. While the mechanics of map production are defined in the methodology chapter, the steps are reiterated in figure 6.2 below to demonstrate how elements of the process resonate with complexity discourse. Through the learning process of the mapping exercise a schema of disadvantages associated with the use of GIS packages was developed (see table 6.2). Since the method was an iterative process where the results of one stage informed the next it seems fitting to recount the process, here, in the findings chapter.

The phase was a learning curve pitted with mistakes, dead-ends, challenges and lessons learnt. Problems were encountered in deciding on the parameters for data display and concepts of complexity theory were reflected upon to move forward. In essence, the notion of fuzzy boundaries helped to move beyond tentativeness regarding those data to be included and those to be omitted. Cartography texts such as Monmonier (1996) were consulted to satisfy the standards of contemporary map presentation in terms of the inclusion of a north arrow, scale bar, title and symbology key.

Table 6.2: Limitations associated with GIS identified during the mapping exercise

Shortcoming
Paucity of good quality data
ArcMap® highly sophisticated tool for analysis but less user-friendly for novice users
Inferring causality by overlaying information especially pertinent in the health context
The 'so what?'question
Cluttered meaningless maps

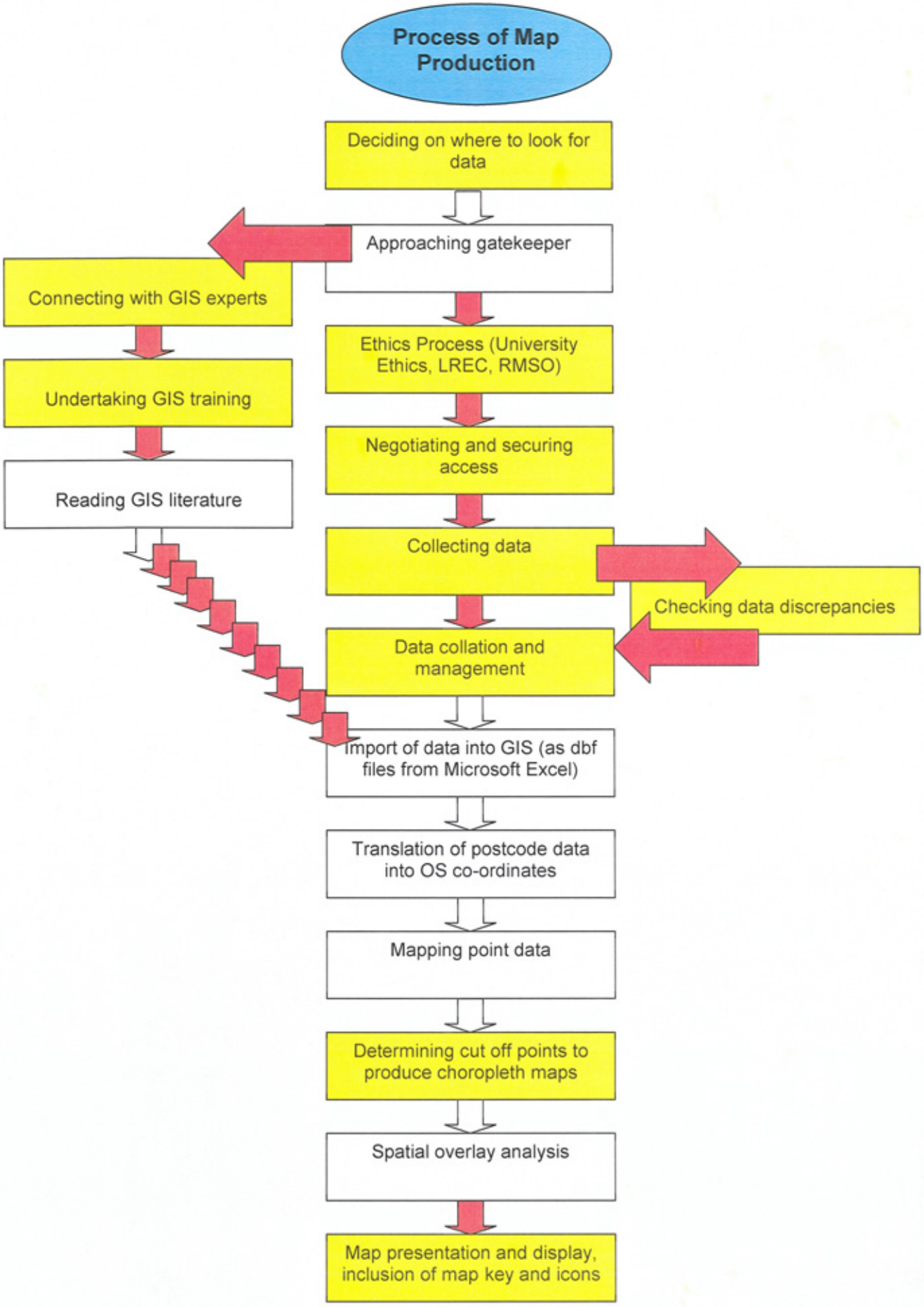


Figure 6.2: The mechanics of map making. Contingent and dependent processes are highlighted by red arrows and non linear activities are illustrated as yellow boxes

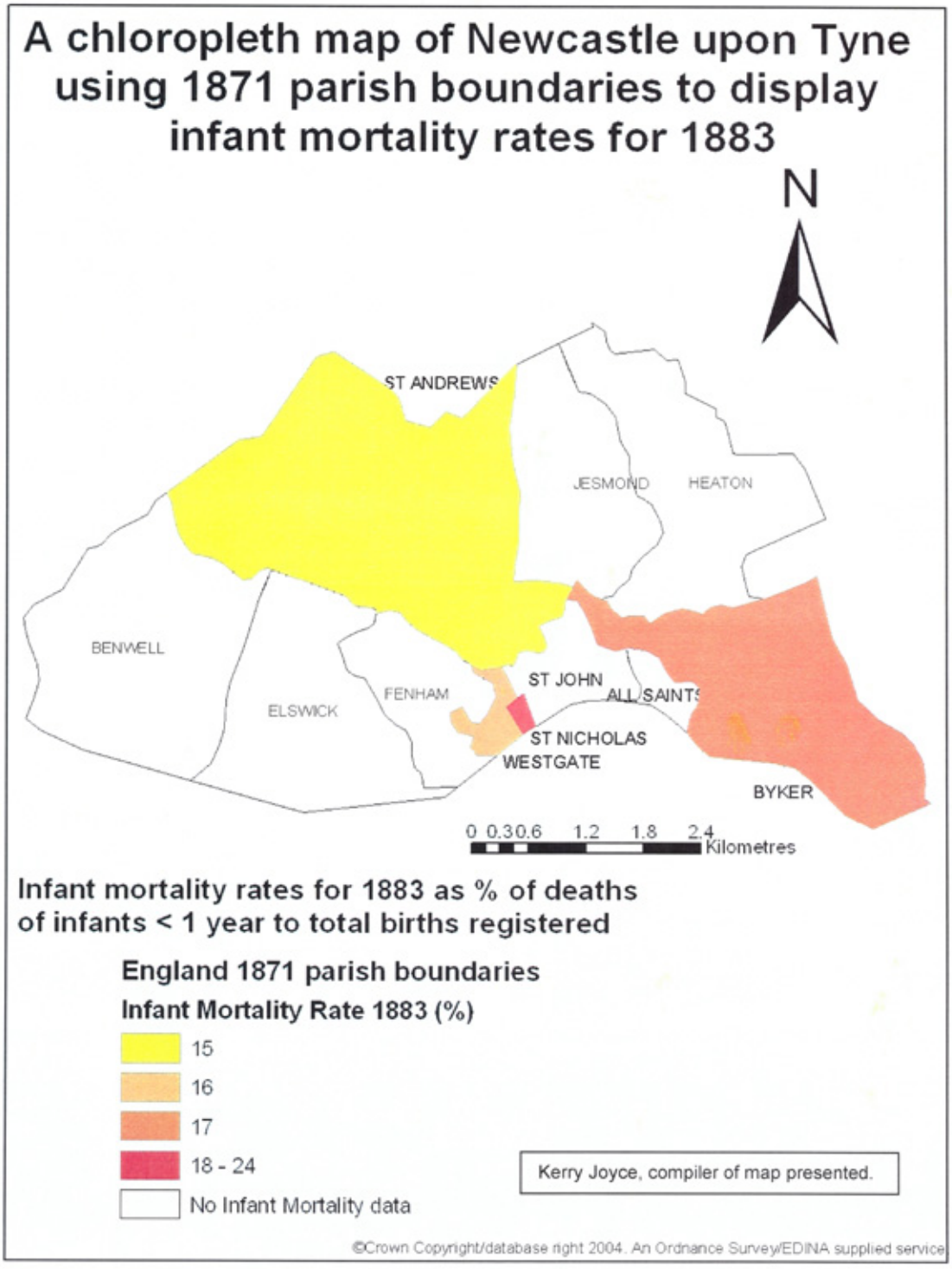
6.2.5.1 Determining spatial boundaries

GIS texts warn against the use of inappropriate map boundaries because it can lead to erroneous data presentation. The modifiable areal unit problem, which is a common pitfall for novice map-makers, arises when artificial units are imposed in analysis leading to spurious data patterns (Heywood, Cornelius and Carver, 1998). To illustrate, Schuurman (2004) describes the example of unemployment rates which at ward level might appear relatively high but when aggregated to the level of district or city the figures are not so outstanding. Smaller geographical areas are preferable to facilitate fine level analysis data but pragmatics come into play as many attribute datasets are not available for geographies lower than ward level. In this exercise super output areas (SOAs) were chosen where possible and in cases where older data were unavailable at this level then ward boundary data were employed (for example, the demography data on children, see the mapping report, p. 7, Appendix I).

Temporality is an important issue in public health as it is just as important to look at what went before - in terms of health indicators, demography and policy - as it is to consider the situation contemporaneously. As depicted, in figure 6.3, higher numbers of infants died in the St Nicholas' and Byker parishes in 1883. The corresponding areas score high on the index of multiple deprivation today. According to Davey-Smith and associates spatial patterns of inequality can remain largely unchanged over time (Dorling *et al.*, 2000).

As with many sources of historical data there are gaps in the dataset; infant mortality rates are absent for a number of parishes represented in white. The GIS map representation is limited further as there is potential for the data to be misinterpreted or misunderstood if comparisons are made on the basis of absent data.

Figure 6.3: A map showing historical data on infant mortality rates to demonstrate how incomplete data limited use in the mapping exercise



6.2.5.2 Determining banding levels for attribute data

Problems exist in determining the banding range for data display, that is how to decide on the cut off points. The method of banding employed can dramatically alter the appearance of a map and therefore can impact on communication and interpretation. For example, in the two figures below the same data are presented but different banding levels are employed to form two visually distinct maps. In figure 6.4(a) data are displayed using quartiles in contrast to equal interval banding in figure 6.4(b). Mindful of this concern, the spread of the data was examined graphically before choosing banding levels. For the maps displaying soil and water measurements (figures 6.6 and 6.7 respectively), banding levels were chosen so as to demonstrate which sites exceeded national standards. The caveat associated with such a schema is that it is impossible from the map to determine where each point is within each banding range, that is, whether it is at the lower or upper level of the range.

From a public health perspective it is possible that the reader could assume an erroneous understanding of the data based on a visualisation, which fails to include a measure of data variation or indeed an indicator of statistical significance. It is hoped, however, that public health practitioners will build on the ideas of inter-disciplinary and collaborative practice where multiple strands of evidence are considered before conclusions are drawn. As proponents of complexity theory suggest, the connections and inter-relations between elements of any system are as important as the elements themselves (Plesk and Wilson, 2001)

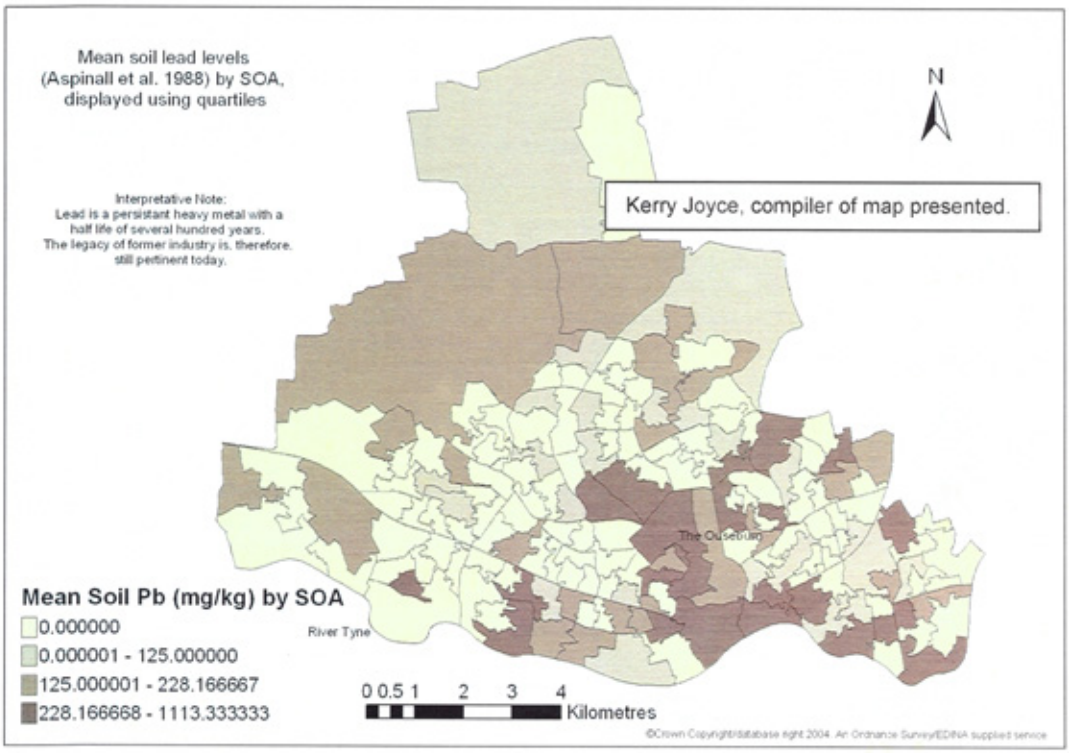


Figure 6.4a. Soil lead levels (1988) displayed using quartiles

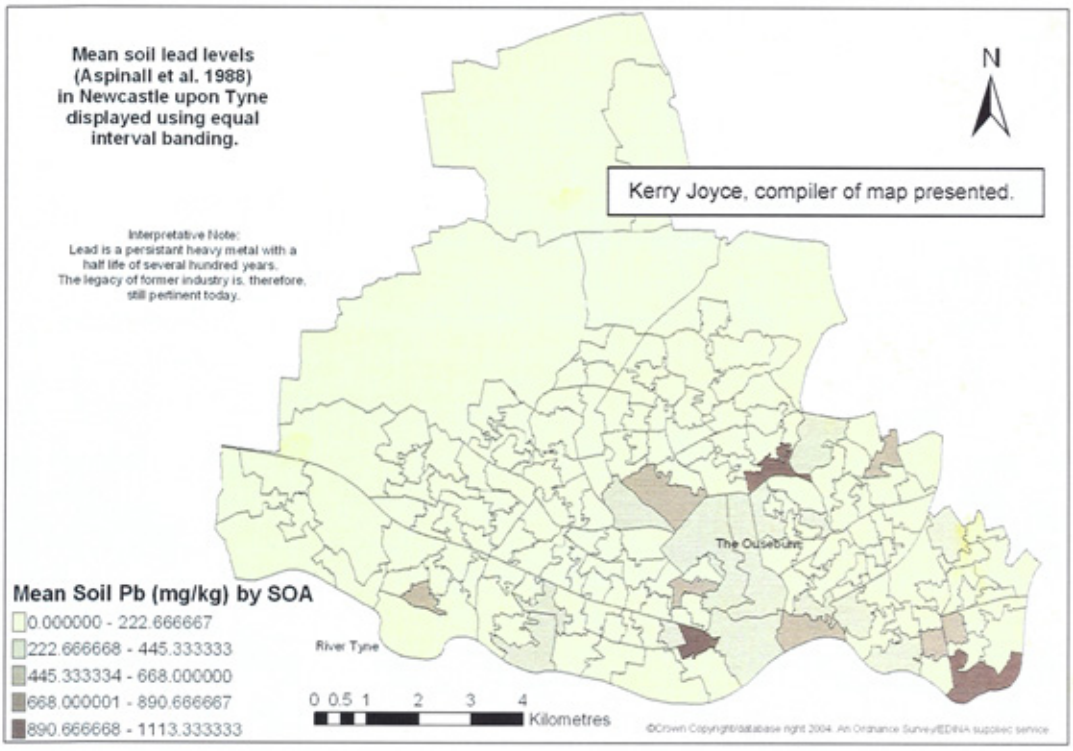


Figure 6.4b. Soil lead levels (1988) displayed using equal interval banding

6.2.5.3 Use of colour - clarification or confusion?

Colour has a myriad of uses in map-making: (i) to label; (ii) to measure; (iii) to represent and (iv) to decorate (Tufte, 1990). Use of colour in visual representations is neither a simple nor a facile activity so it was no surprise that participants cited colour as an ambiguous issue in the mapping report. In one sense the use of contrasting colours made it easier to discriminate between different areas on the map but when too many colours were used the maps felt more like 'colour by number' pictures rather than robust and scientific evidence displays. As is demonstrated in the sample of maps included in this chapter, there needs to be some form of continuity between colour palettes used. For example, by using a palette of yellow/red to represent soil lead contamination in one map (for example, figure 6.8) and then moving to green/blue in another display of soil lead levels (for example, figures 6.9) could cause confusion to the reader and may lead to misinterpretation of the data. Furthermore, it would be a mistake to use colour only to improve aesthetics since it has the power to provide clarity and impact to augment the power of maps as sources of evidence.

Tufte outlines four basic rules for the use of colour in information displays:

(i) Limit the use of strong or bright colours to highlighting key pieces of information (avoid colour clutter).

(ii) For aesthetics do not place bright colours and white next to one another.

(iii) Background colours should be subtle or neutral; grey is a good choice.

(iv) Weave colours throughout the display to provide unity and coherence.

The map–making process attempted to follow these guidelines to produce clear and informative displays, which endeavoured to illuminate rather than distract the audience from the messages and meanings behind the data displays. The power of colour as a communication device is demonstrated, using a simple choropleth map of Index of Multiple Deprivation for Newcastle (refer to figure 6.5 below). A colour palette ranging from yellow (least deprived) to red (most deprived) is employed for the simple reason that red is viewed by

many in Western society to signify danger. In this way the use of colour is intuitive. Like other tools, however, colour has the power to mislead if used with little forethought or insight. Indeed. Monmonier contends that black and white maps might be more "*readily and reliably decoded*" than their multi-coloured counterparts (Monmonier, 1996, p.163).

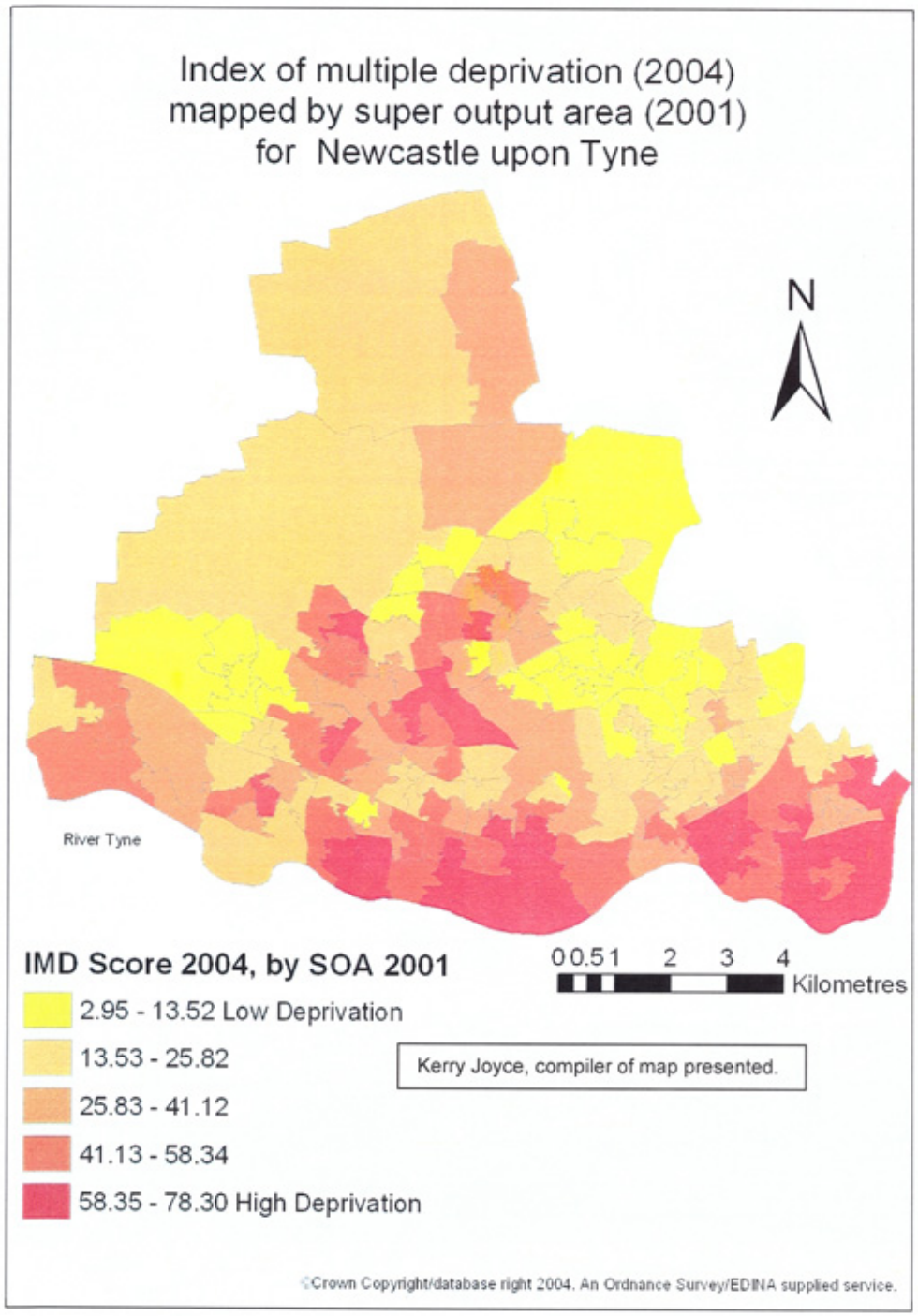


Figure 6.5: A choropleth map demonstrating the power of colour (using the colour palette yellow through to orange and red) to communicate increasing levels of deprivation

6.2.6 Issues specific to the research problem of childhood lead exposure

6.2.6.1 Patterning of lead contamination

As highlighted by Aspinall, Macklin and Openshaw (1988), Mellor and Bevan (1999) and Mellor (2001), lead contamination can often adopt a hot spot patterning whereby areas of low soil lead surround foci of high contamination. Due to the use of regular grid sampling as employed in the studies by Aspinall, Macklin and Openshaw (1988) and Vizard and Pless-Mulloli (2003) such contamination may be missed. Figure 6.6 shows a point map of soil lead data

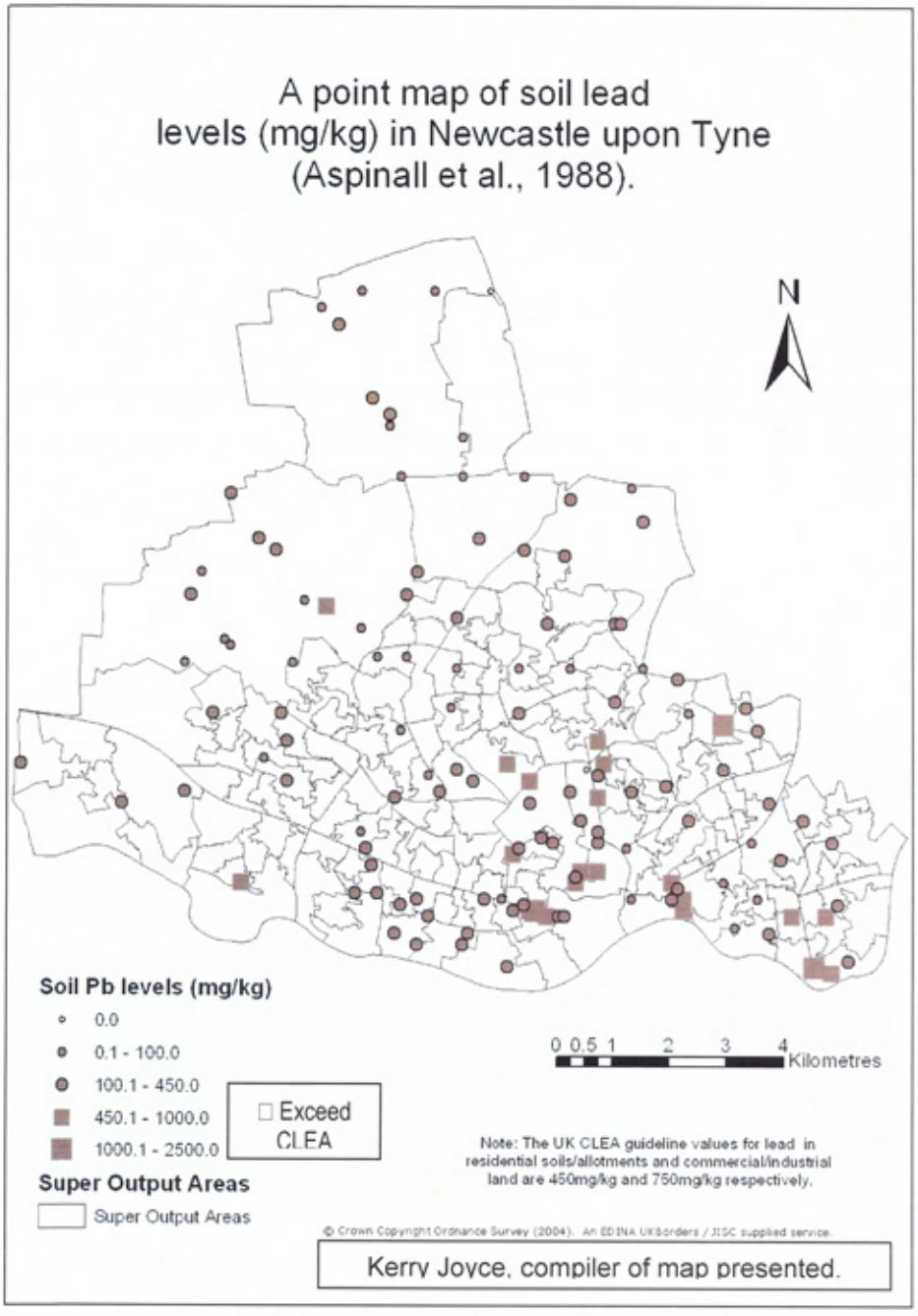


Figure 6.6: Map showing point data from a study conducted in the 1980s demonstrating the limitation of data currency

where levels exceeding the national guidelines (Contaminated Land Exposure Assessment, CLEA) are highlighted using different symbology. Again these data have limitations: they were collected in the 1980s and a sparse sampling grid was used.

6.2.6.2 Exploring possible associations with (i) reduced educability and (ii) low birth weight

An important consideration for meaningful data display is the inclusion of denominator data. In terms of GIS mapping there is a limit to how much data can be displayed on a map, so a series of 'contextual maps' (pages 5–8, Appendix I) were included in the report to provide baseline information that could be used to make sense of the map overlays.

When considering possible associations between environmental lead and variables such as educability and birth weight a mass of confounding factors come into play. It would have been anomalous to believe that an exercise such as this would illuminate underlying causal pathways given the complexity of the interactions. The reason for the integration of education and birth weight data was to demonstrate the use of overlay operations within GIS to integrate both human and environmental data. There are thorny issues surrounding the notion of intelligence and educability and the use of IQ as an indicator. Similarly, birth weight is thought to be determined by a multiplicity of social, physical, environmental and genetic elements. Complexity endorses the view that causality is contingent and multi-factorial; thus disentangling this complex web of determinants using the mapping approach would be untenable. Moreover, the maps were used to explore possible links and to demonstrate how GIS could be used to overlay disparate datasets in line with the underpinning theoretical approach.

To an epidemiologist whose aim is to satisfy the rigorous criteria for causation this exercise may be regarded as futile but to the public health practitioner, operating in a multidisciplinary environment, the use of GIS to integrate multiple and disparate data to visualise and explore the complexity of current public health issues might be more meaningful. From a complexity stance, data is not simply valued using a straightforward hierarchy (such as the hierarchy of evidence employed in quasi-experimental models). The various attributes and inter-relations demonstrated in less traditional forms of evidence

are valued in terms of how they contribute to understanding as a whole. Integrating disparate strands of data and visualising information in new and different formats can add perspective and introduce new dimensions to the evidence base in a bid to challenge existing thinking about a particular issue[10].

Mapping variables together may imply causality leading to erroneous conclusions. For example, with reference to figure 6.7 below, inferences could be made that elevated water lead levels correlated with super output areas with higher deprivation scores. Such interpretations are erroneous because they do not take into account sampling strategy and population density. Despite the incapacity of GIS to provide evidence on cause and effect, maps can be used to demonstrate repeated patterns of association to support other strands of evidence. In this way the maps can act synergistically to strengthen and reinforce arguments. Complexity theory enables the public health practitioner to take into account multiple sources of evidence and to make informed decisions using the data at hand whilst remaining aware of the caveats associated with each branch of the evidence base.

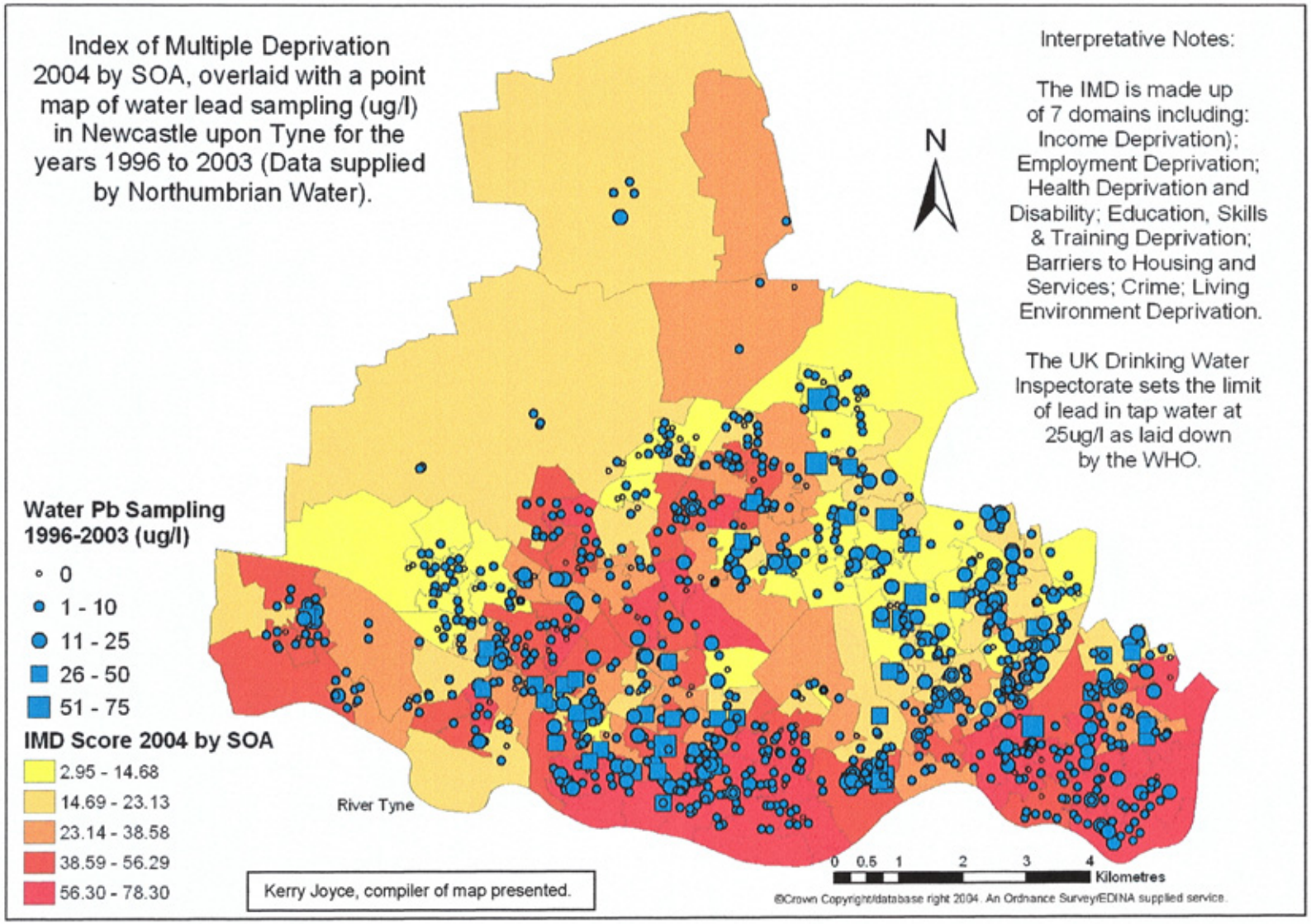


Figure 6.7: A map to demonstrate the risk of misinterpretation in terms of colour continuity and density of symbols

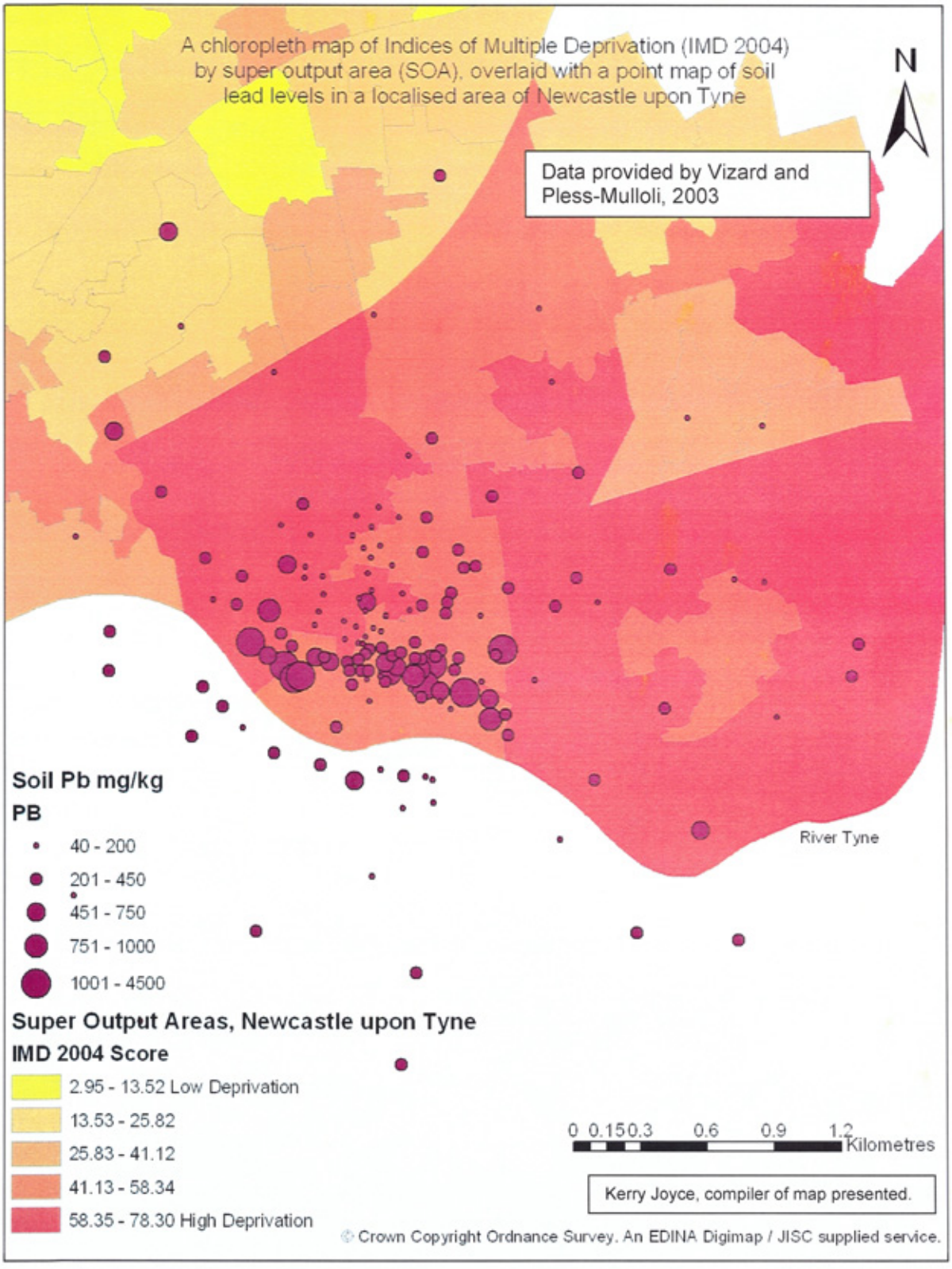


Figure 6.8: A map to demonstrate how the geographical scope/coverage of a secondary dataset (Vizard and Pless-Mulloli, 2003) limited its use in the case study

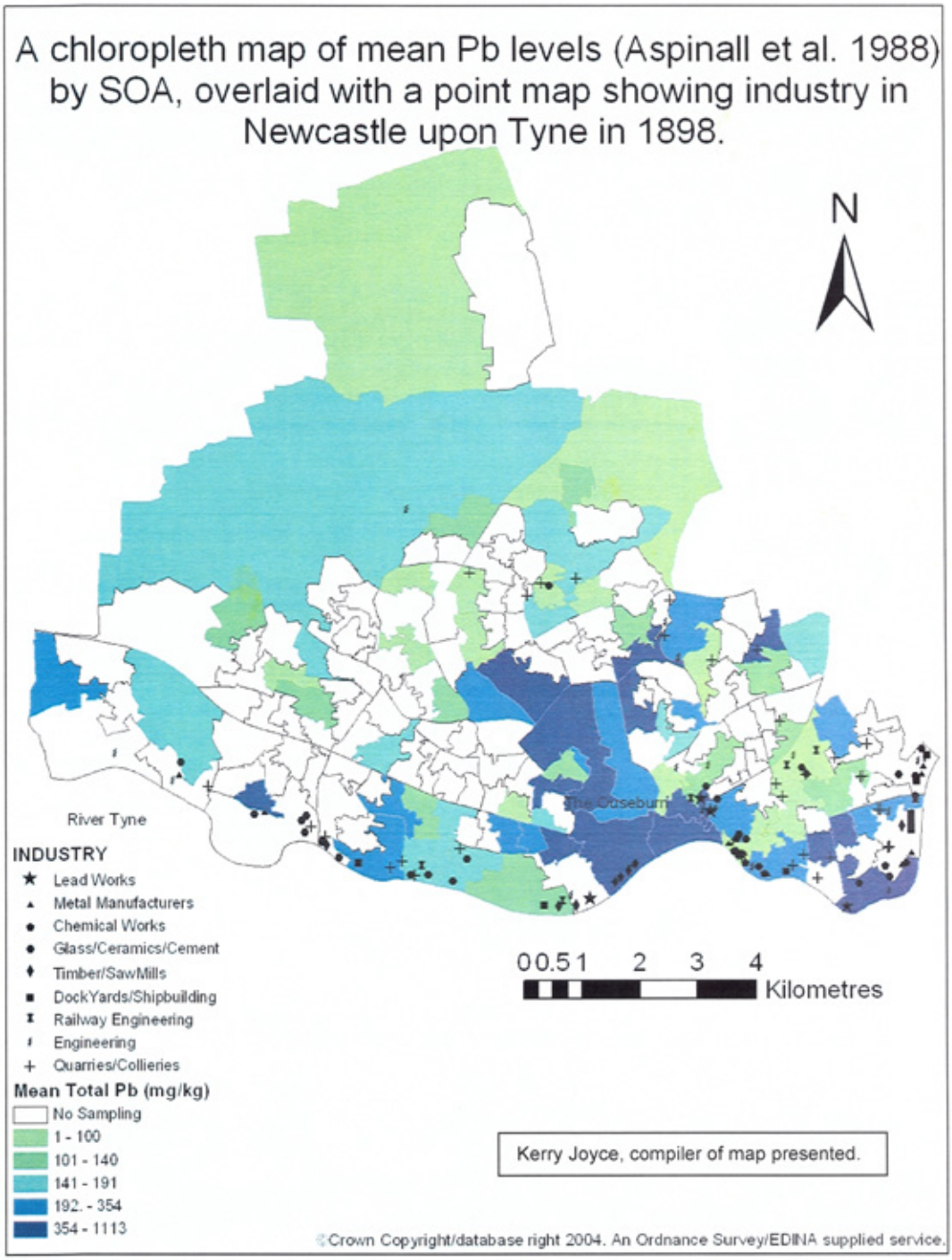


Figure 6.9: A map showing soil lead levels overlaid with historic industry data to demonstrate the difficulties in balancing contrasting demands in the map making process: (i) fitting a map to an A4 page and (ii) making the symbology legible

6.2.7 Discussion of the mapping exercise

The mapping exercise was beneficial in enabling understanding of the complexities involved in the process of producing maps and the nuances of GIS technology. GIS mapping was demonstrated to be more than simple number

crunching and the science behind GIS was found to be pivotal in producing meaningful and judicious maps. As Monmonier (1996, p.1) argues, users of maps can be naive to a "*map's power as a tool of deliberate falsification or subtle propaganda*". GIS can be used to misrepresent and even to mislead depending on the aims and, sometimes covert, objectives of the map-maker. With this in mind it was important to display the information regarding childhood lead exposure judiciously without manipulating the data to convey a particular message. For this reason the maps included in the report have little description or explanation. It is for the audience to make their own interpretation.

Parallels were noted between the use of GIS in the public health context and features of complexity theory. Complexity discourse promotes the notion of convergence and the idea of nested systems. Within GIS multiple layers of a map are related and a change in one layer may impact on the system as a whole to a greater or lesser extent. These ideas were explored in depth in the qualitative interview phase with public health decision-makers and are discussed further in chapter 7.

6.3 Engagement with the mapping report

6.3.1 Interview discussions

The order of the interviews reflected the incorporation of data into the GIS that is the organisations contributing environmental and demographic data were approached before those agencies responsible for the health and development datasets. As the study progressed, snowball sampling emerged as the strategy of choice and, in line with complexity discourse, strict adherence to rigid order became inconsequential as a pattern emerged naturally. All participants were asked – as an open-ended question - to comment on the mapping report. A range of issues were raised by interviewees, some of which related to the quality of the report in terms of GIS outputs, while some focussed on presentation quality and others concentrated on the public health problem of childhood lead exposure. Several respondents confessed they had not read the report in depth and commented more on GIS as a means of presentation, which was equally valid and constructive. The salient issues highlighted by respondents are presented in the following three sections.

All participants were familiar with the concepts of GIS and had seen GIS outputs in the past. Furthermore, a significant number of interviewees had first hand experience of GIS software. One respondent from an agency with a clear population health remit, fully engaged with the report from the start of the interview without being prompted and used it to demonstrate particular strengths or weaknesses of the GIS approach. Although it was tempting to categorise or label respondents as 'GIS-philic' or 'GIS-phobic' this approach did not seem to fit with the research paradigm of complexity. Participants were neither protagonists nor antagonists of GIS technologies, instead interviewees seemed to recognise both the strengths and limitations of GIS technologies and their outputs. In the language of complexity there were a number of internalised rules or attractors, which affected how GIS was valued in decision-making. These included factors such as familiarity and experience with GIS and understanding of data management and manipulation issues.

6.3.2 The meaning of mapping in public health

In the world of geographers and cartograhers, ESRI (the developers of ArcGIS®) describe GIS as:

> *a system for management, analysis, and display of geographic knowledge, which is represented using a series of information sets*
> (www.esri.com/software/arcgis/concepts/overview.html)

The National Library of Medicine (NLM) define GIS as:

> *computer systems capable of assembling, storing, manipulating and displaying geographically referenced information i.e. data identified according to their locations*
> (http://www.nlm.nih.gov/cgi/mesh/2003/MB_cgi?term=GEOGRAPHIC+INFORMATION+SYSTEMS)

Similarly, the World Health Organisation employs the definition of GIS as:

> *a computer-aided database management and mapping technology that organizes and stores large amounts of multi-purpose information. GIS adds the dimension of geographic analysis to information technology by providing an interface between the data and a map. This makes it easy to present information to key decision-makers quickly, efficiently and effectively*
> (http://www.who.int/health_mapping/gisandphm/en/)

Each definition lists a plethora of functions inherent to GIS packages. Interestingly, and perhaps unsurprisingly, the WHO definition is more commensurable with some of the functions valued by interviewees, namely the collation of multiple data and the presentation of the information in map form for communication purposes.

None of the definitions, however, mention GIS as a methodology or even a method in research. Despite the majority of participants focussing on GIS for data visualisation and presentation and failing to acknowledge the functions of data manipulation and analysis, both functions are present in two of the definitions (ESRI and NLM). When asked what the term 'mapping' meant a multiplicity of responses were received. One participant felt that mapping was "*making a list*" whilst others saw mapping as a process of "*matching*" or "*benchmarking*".

> *I mean mapping in the public sector is almost a joke bureaucratic term. Everything has to be mapped. In fact I think I more often use and hear the term map that isn't referring to GIS or indeed any other diagrammatic map, talking about a word map and I use it myself in that context a lot* (H, 6/279).

> *Some just want to benchmark really quickly and they don't always want loads of graphs and things that it takes them ages to wade through* (R, 2/76)

Decision-makers from NHS related organisations differentiated mapping from GIS and overall there was a feeling that the term mapping pervaded more than just GIS applications. It is clear from figure 6.10 that definitions and understandings were multi-dimensional and shaped by the background of the respondents.

6.3.3 Initial perceptions of the report

The report was designed to stimulate debate and by drawing on the contentious issue of childhood lead exposure, strong opinions were expected. A number of interviewees, particularly those in the environment sector, were reluctant to talk about the issue of lead exposure explicitly. Many respondents, however, were positive about the report, citing the clear and colourful outputs as a direct means of visualising results:

> *For me personally you can see the results clearer....I think it's more colourful, you can see directly, you can see straight away by looking at the key you can point out what the results are* (O, 2/91).

The immediacy of GIS maps was recognised as an important and useful property. Indeed, maps were perceived, generally, to be a successful communication device to contextualise the debate and to illustrate the salient messages delivered in the text of a report. The importance of GIS for communication was captured by two interviewees who commented:

> *It is something that gives a graphic demonstration of a point you're trying to make* (F, 16/762).

> *I always think that diagrams are always useful anyway to sort of put things into context. And it just breaks up some of the wording because it can be quite heavy can't it?* (M, 14/672).

Others were encouraged by the use of the GIS approach to explore a problem in depth. The pragmatic concern of making the best use of the data available seemed to be understood. Most respondents were aware of the inadequacies of datasets and the limited availability of high quality data.

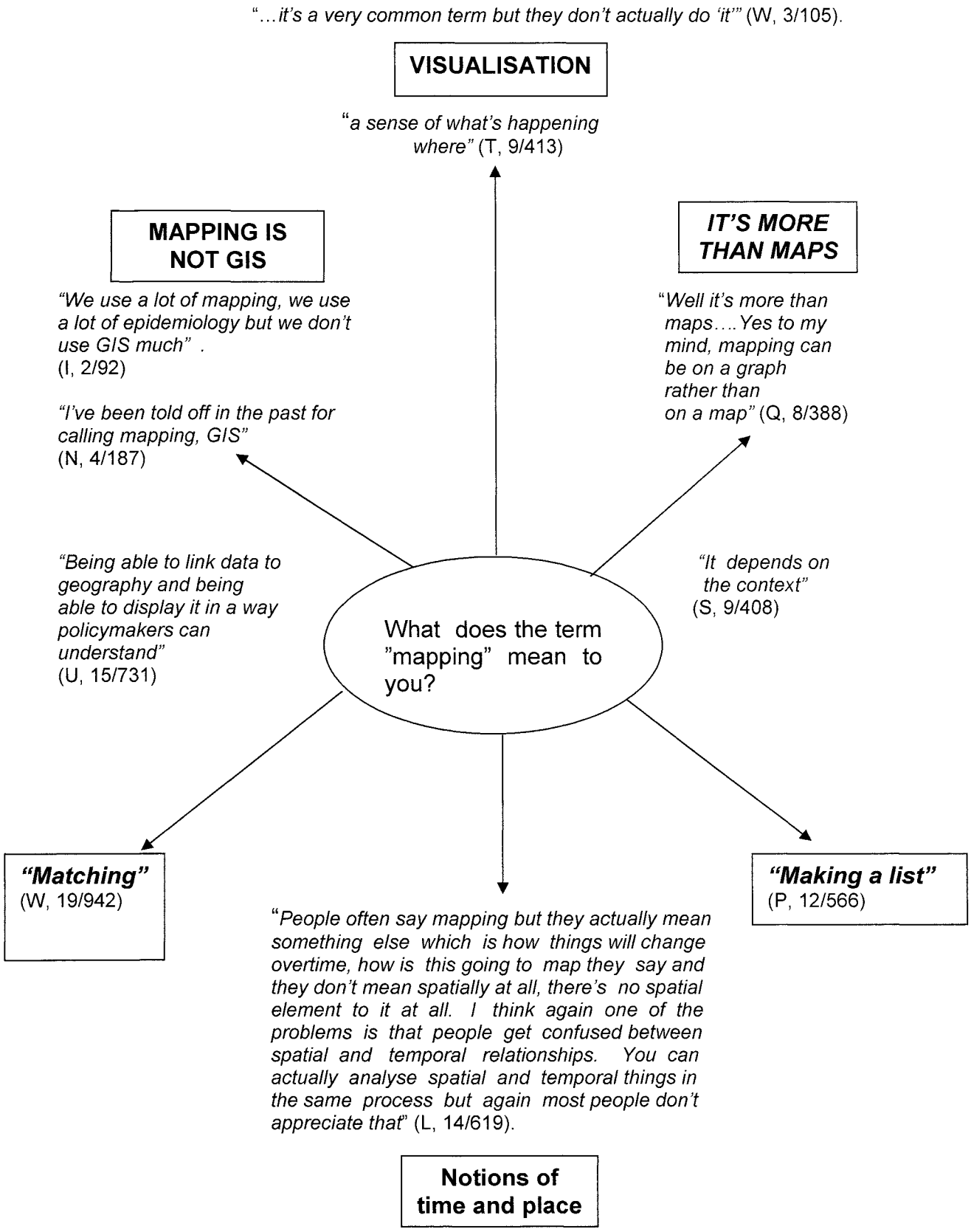
> *You're using the best data you can get your hands on and it looks pretty comprehensive. It's telling you a story dataset by dataset as to what's going on ...It's a very interesting report I think. I wish we'd done it. I'd like to do something like this and really dig down into the problem, particularly working with an organisation who is going to benefit from it* (G, 16/703).

This discourse flags up the use of GIS for story-telling as a means of unpicking and explaining an issue in an accessible way. Similarly the ease of using GIS to explore data was highlighted:

> *On the other hand it does allow you to kind of explore data in a way that it would be difficult otherwise* (N, 14/692).

The value of GIS for data presentation was appreciated particularly in the light of comparisons with other forms of data display such as graphs or tables. This aspect will now be discussed.

Figure 6.10: The meaning of the term 'mapping'



6.3.4 GIS versus tables and graphs

When asked to compare data presented in tables, graphs and pie charts (pages 10-12, Appendix I) with the same data presented in a GIS map overlay (page 9, Appendix I) respondents were able to clearly identify the benefits of a GIS approach. One practitioner commented that maps tend to be more memorable in comparison to tables or graphs:

> *It's so much more effective. I do remember, now I'm looking at these...I have seen some staggering maps over the years that stay in the mind, whereas the same information in other forms hasn't* (H,12/574).

Tufte (1994, p.52) contends that visual rather than tabular displays of information can *"encourage a diversity of individual viewer styles and rates of editing, personalising, reasoning and understanding".* Tables of numbers can show variation within a dataset but it is difficult to compute what the average and minimum and maximum values are. Whether these perceptions are derived from personal experience, beliefs and values or whether they are led by organisational didactics is a matter of debate.

The comments are reflective of the status/use debate, which is explored further in the thematic findings, section 7.5). Interestingly, none of the participants interviewed broached the issue of secondary data and how that may impact on the use of GIS evidence. As discussed in chapter 4, secondary data are plentiful but rarely accessed to examine topical public health issues. This may in part be due to a distorted perception that high quality research has to involve the collection of primary data. While evading discussion of the subject of secondary data explicitly, it should be mentioned that a number of interviewees did point to the importance of avoiding duplication of effort. Decision-makers, therefore, may well have been supportive of the use of pre-existing datasets for secondary analyses.

Data presented in GIS map format were felt to be more accessible than the same data represented in tabular form. GIS, however, was seen only as a precursory investigative technique rather than an in-depth analytical tool by some of those interviewed, particularly those in the environment sector.

> *It's quite clear that presentation in a geographical form is more easy to picture than it is in tabular form but I'm not sure, ultimately, that it tells you more than where to look. So you can overlay areas and it picks up hotspots but I'm not sure that you can make any real conclusions from a visual inspection of overlaid geographical information. All it does is point you in a direction to do further research to present data in a different way. I really don't think that you can draw conclusions from the presentation of information it just gives you an indication* (A, 7/326).

This view seems to reflect the respondent's own 'paradigm' or world-view in that he is looking for linear logic, defined outcomes and evidence to demonstrate causality, which is not provided by GIS. Such a response is at odds with complexity's anti-positivist stance. By focussing on the need for deterministic evidence the interviewee misses the full and rich picture of inter-relationships provided by GIS.

Similarly, another participant suggested that GIS may not be an appropriate means of presentation depending on the audience. For example, a lay audience might be bamboozled by the cluttered map displayed on page 13 of the mapping report (water lead sampling mapped over index of multiple deprivation by super output area, see Appendix I). Conversely, if the audience requires numbers or statistics, more information may be required. As the quotation presented below demonstrates, many decision-makers still subscribe to the patriarchal view of 'we know best', which is both condescending and against the grain of complexity thinking.

> *With your audience that extra detail (e.g. percentages) would mean nothing to them. But to other people who are wanting to say "right okay where are the highest levels and what's the difference between the lowest and the highest and what's the average" then you would need all of that (J, 13/612).*

The caveats of misreading or misinterpreting maps were highlighted. When dealing with graphs or tables it is less easy to draw conclusions without raising further questions. In some instances problems may arise if conclusions drawn from GIS outputs are unsubstantiated or erroneous. In other cases detail may be lost within the map so that the more subtle interrelations in the data remain hidden.

> *But I think with a map it's easy for someone to kind of I suppose pull off what they think is a final message whereas with a graph or table it's perhaps easier to see that there are other questions that need to be answered...I think you need in doing GIS to try and avoid introducing false artefacts in that way as well and saying just because I've made the breaks in the groupings in the way I have which suggests all these ones together. Whereas in fact if I'd done the breaks slightly different I might have been able to tease out a bit more of the difference between these ones* (D, 21/1025).

The comments around the importance of well thought out class boundaries were highlighted and corresponded with the researchers own thoughts and anxieties encountered during the map- making exercise.

Several respondents emphasised the need for caution when examining causality and it was clearly understood that just because two datasets are

overlaid together this does not imply anything other than a coincidental relationship. In some instances, however, visual spatial correlations might actually represent a real relationship and GIS mapping should not immediately be dismissed for presenting so-called 'soft data'. Accordingly, the benefits of using GIS to explore spatial patterning to produce supportive evidence were not refuted. It was recognised that potentially dangerous misunderstandings and misinterpretations could emerge if the data were not used and presented appropriately as evidenced below:

> *I think the only thing I would say with regard to, not your report in particular but reports in general, where two datasets are brought together, is that quite often it can be picked up by the press…So actually, you know you shouldn't just take this at face value….It's a very powerful tool and I think sometimes it should be used with caution perhaps* (E, 16/765).

> *I think any situation that is highly politically charged like the leukaemia clusters and power stations for example, some people, because of the sensitivities, don't accept the evidence or doubt its power because it isn't demonstrating what they want it to show* (W, 16/774).

Interviewees tended to be wary of maps implying cause and effect, which again is indicative of the dominant model of understanding that applies linear logic and attempts to reduce and simplify complex public health problems to tangible and measurable components. A number of respondents believed, however, that the map overlays were valuable for integrating multiple strands of data:

> *I think it's illustrative of the way you can bring a lot of different information together….You will often go to a meeting and people will have a point of view and it is good to have some information available to answer any questions raised. And if you have access to information from a variety of sources you can, if you like, head people off at the pass by saying well the information is here, we foresaw that such a question would be asked because people often have strong opinions of cause and effect* (F, 15/733).

This particular respondent was able to see the pragmatic use of GIS outputs as evidence to facilitate decision-making processes in discussions, meetings and forums. Thereby demonstrating the potential for GIS maps to be used as straightforward and accessible evidence to support or refute contentious or costly decisions.

6.3.5 Technical issues relating to GIS concepts, use of data and quality of map representations

Several participants volunteered comments and opinions on issues pertaining to technical aspects of map making. These views tended to be held

by respondents with experience of GIS who were more likely to be familiar with the range of functions in the GIS toolbox. The concerns raised included the lack of statistical significance provided in map data, the absence of denominators for comparison and the limitations associated with so called 'pretty picture' data.

A further pertinent assertion was made by one participant who argued that GIS was useful only in early analysis as other packages would need to be employed to examine causal relations and to attribute a level of statistical confidence to the results. When interpreting an overlay of water lead data and index of multiple deprivation a number of questions were raised regarding population density and the possible erroneous assertion that higher lead levels were found in more deprived areas of the district.

> *The one on Index of Multiple Deprivation overlaid with a point map of water lead sampling, is do you get multiple deprivation in high population areas? Our random sampling program is also based on population so we're likely to take more samples there. So do you get a correlation only because of the sampling population? Again I'd just say that it points to a trend but it does need further work. Orange is low deprivation and it would appear that we have fairly low lead sampling results. But I'm not sure that actually tells you anything because you don't have a huge number of people there. Maybe the data needs to be presented with some kind of normalisation in there* (A, 7/342).

Clearly, the issue of lead contamination is complex, non-linear and multi-faceted. The above dialogue emphasises the tensions around putative associations between lead and deprivation. Anecdotally, one might expect that individuals living in deprived areas would be at a disproportionately high risk of lead exposure. Indeed deprived communities are likely to be located in areas of contemporary or historic industry or near major road networks. Equally housing in deprived areas may still be equipped with lead pipes or may have deteriorating lead paint indoors or outside. Whether lead is a threat in all or any such areas remains to be seen but for a government committed to reducing health inequalities, lead is an additional threat, which should be recognised. From a public health perspective, communities living in deprived areas are exposed to a barrage of assaults, not just lead and environmental contaminants but also food deserts, crime, poor housing and transport. Thus, there is a real need for decision-makers to be aware of all potential factors (no matter how contentious or unwieldy) that may contribute to the widening gap between affluent and deprived areas (Davey-Smith *et al.*, 2002).

The respondent goes on to highlight the inability of the maps to demonstrate what is actually going on in terms of the overlays. The decision-maker (from a utilities agency) speculates that because there is no information displayed regarding population density then the data are meaningless and ultimately futile to decision-making processes in his organisation. From a complexity stance, value can be seen in the data displays, rather than posing deductive questions about what is fact or absolute truth, the complexity theorist might wish to examine what one might learn from the map overlays and what issues could be investigated further.

As alluded to in the extract above, technical issues such as determining the bandings for data display flag up important concerns as they can dramatically alter data visualisation and accordingly interpretation. To facilitate judicious display of a particular dataset it is necessary to understand the distribution of the data before deciding on the most appropriate banding, for example equal intervals or Natural Jenks banding[11] (ESRI, 2006). It follows, therefore, that different meanings can be taken from the maps. The common adage that statistics can lie also appears to be true for map representations. Indeed, one participant highlighted that very fact and implored the responsibility of the data provider to use and represent the data accurately and judiciously.

> *To some extent I suppose there is a responsibility to GIS to make sure that the right message is coming out. If you follow the line that a lot of people find it easier to understand something when it's presented to them in that form it's also easier for them to misunderstand it* (D, 11/543).

The fact that maps are accessible and open to interpretation means that there is a responsibility for the data provider or map-maker to represent the data in such a way that avoids communicating an erroneous message. This confers with it an equal responsibility to listen to the audience's concerns and to discuss and address the maps possible ambiguity. Visual images are often more evocative than statistics, presented in graphical or tabular form, so the person making the map has a responsibility to create a map representation that is clear and not confusing.

> *It depends if you want to put a specific message across you might want to present things in a certain way but if you want to be fairly anodyne about it and say here are the facts you decide you need to be a bit more careful about how you do that presentation and that I suppose is where the analytical bit comes*

[11] Jenks Natural Banding is a method of statistical data classification that partitions data into classes using an algorithm that calculates natural groupings within the data values based on the data. Jenks' optimization seeks to reduce variance within groups and maximize variance between groups.

> *in....The problem I find is the 'bearing in mind', those caveats that people ignore. 'This shows such and such' but if you thought about it a bit it's not quite as clear as it seems* (D, 21/1044).

The above comment resonates with the intention of the report to provide data, which were open to interpretation and did not infer any conclusions about the map representations. This strategy conflicts with the ethos of current public health practice which is characterised by a culture of 'targets' and 'results' and an explicit need for answers. Policies continue to adopt monotechnic or linear tactics to deal with complicated and socially embedded problems which are inherently non-linear. Perhaps this explains why several participants were seeking 'an answer' or 'a conclusion' when interacting with the mapping report. Despite increasing recognition that the 'one size fits all' approach is anomalous and debilitating, many policy initiatives remain entrenched in this reductionist way of thinking. When adopting a complexity stance in terms of decision-making with maps, the participant becomes a significant actor in the process and has to critique each of the GIS outputs in his or her own mind to understand the nuances of the process of map making and the various pitfalls and problems that can be encountered. The focus is on 'what can we learn' and 'how can we move forward' rather than 'this is the effect, what is the cause' models of thinking. These issues are reflected upon in chapter 7.

A further technical problem concerned map boundaries. Interviewees experienced in the use of GIS packages criticised the use of administrative boundaries as there was a possibility that this could produce artefacts in the data, which may lead to the formation of spurious conclusions. As one contributor stressed:

> *Where you're looking at mean soil lead levels in a way it is unlikely the pattern really looks like a pattern based on boundaries* (N, 13/609).

Erroneous patterns can be produced through the use of certain geographic or political boundaries, where areas are not matched in terms of population density and land use (urban versus rural). For example in figure 6.9, showing soil lead levels (1988) overlaid with historical industry data (1898), the Woolsington ward stands out visually but it would be a mistake to interpret this as significant because this particular ward is a large rural area where few soil lead samples were taken. The mapping report could be improved by amending the area units of analysis imposed by politically or historically rigid boundaries. One of the advantages of the GIS approach is the capacity to

employ different area units. By changing boundaries, however, the ease of comparison over time is reduced. The introduction of the new census output areas makes it simpler to amalgamate localities to create new areas of equal size or population for comparison.

When comparing map, table and graph data representations (see appendix I, pages 9-12), maps were favoured for clarity with the proviso that inappropriate map boundaries can give rise to false patterns and artefacts in the data.

> *Clearly, this table, if you want to cover something up this is an ideal way to do it. It is completely un-interpretable whereas a map is a much clearer way of presenting it but at the risk of presenting a spurious pattern that isn't really there because of some administrative boundary where you've got areas not sampled so you've got a gap in it or you're spreading a couple of samples across a huge geographical area* (N, 13/633).

These thoughts were reiterated by another participant who pointed to gaps in the sample for birth weight data, which precluded in depth analysis.

> *This is the graph that looks at weight at birth against soil lead levels. You've got low birth weight in areas where there are no sampling. You've got slightly higher birth weight where the mean soil is quite high. I'm not sure that you can draw any conclusions from that but where you've got lots of data you can do more analysis* (A, 8/357).

It is clear that this response is commensurable with the findings from the appraisal of data sources (table 6.1), which also highlighted data inadequacies. The idea, however, that because the data were not flawless seemed to prevent some participants seeing any real value or usefulness in the information presented. Perhaps, because the data were viewed as complex (in that they were not complete, nor timely nor comprehensive) they became un-manageable and un-useable. Display using GIS techniques may have emphasised these deficiencies in the data themselves and acted as a further barrier. Conversely, the complex nature of the issue itself, childhood lead exposure (socially embedded, nonlinear relations with deprivation, multiple dimensions and cumulative effects) could alone have brought about this apathy towards the data and the way the problem was written off as un-approachable. The notion of unmanageable complexity will be discussed in depth in chapter 7.

6.3.6 The absence of statistical detail

The lack of statistical indicators (for example p values for significance or confidence intervals) was perceived as a limitation of the maps. This was not a consistent finding as it tended to be 'numbers' people, that is those with a

quantitative background, who commented on this particular inadequacy. Without intending to generalise to the broader field, certain patterns are discernable across participant responses. These patterns will be discussed further in chapter 7 but it is useful to note that there were marked differences between the perception of maps by quantitative public health practitioners compared with those without this type of experience.

> *Well statistical analysis of data gives you a degree of confidence about what you present because you have certain rules around the statistical analysis tools that you use. So you can present information in a way that has a degree of confidence associated with it. I'm not sure that the geographical information has a confidence grade that comes with it. It's a presentation of data from which you can make a visual opinion but it doesn't have any degree of confidence does it?* (A, 8/372)

> *Well the main benefit of GIS is that it gives you a different way of analysing data – that's the main benefit. The sorts of techniques you'd use originally is case control studies, well the problem of case control studies is the control. More often controls are identified on the basis of their physical, rather than spatial characteristics, and for a lot of environmental issues in particular, the spatial characteristics are more important* (L, 4/182).

Clearly, there was a need for decision-makers in both NHS associated organisations and environmentally focussed organisations to qualify GIS as a tool in analysing cause and effect pathways. The requirement for a straightforward answer, in the language of statistics, is in keeping with the search for certainty and an absolute truth. The report was criticised by one individual for failing to properly address scientific issues of data analysis such as comparing like with like.

> *I think you've got to be careful though that you are comparing like with like. Just simply plotting numbers of low birth weight I don't think is particularly useful. You've got to compare the low birth weight with the population so it's not just numbers it's actual percentages* (A, 8/384).

To address this concern, the respondent was directed to the contextual map overviews (on pages 5-8 of the mapping report), which provide denominator data for use in visual analysis (eyeballing the data). Whether or not this particular issue concerns problems with the report or whether it is a problem inherent to GIS applications, and the process of map-making itself, is an issue for debate. Practical experience gained through the mapping exercise would suggest that it is the former for the following reasons: overlay analysis tends to work better when overlaying a point data set onto a choropleth map rather than overlaying two choropleth maps. When considering the birth weight data overlaid with the water lead data, the optimum map representation would have used the percentage of low births from the total number of births. This

information would, however, be less amenable to representation using GIS. GIS mapping, therefore, requires some level of compromise and a number of issues to be reconciled before deriving a meaningful representation. In this study the map output was not intended for statistical analysis – rather the aim was to stimulate and engage the audience in open dialogue and debate.

From this it follows that the map constructed depends on the issue of interest and the problem to be addressed. It is clear that for certain types of decision-making processes a more detailed level of analysis is required and simple GIS representations cannot pretend to be appropriate in such instances. But in the same way, when attempting to engage a broad and diverse audience more basic data representations might be more suitable. The findings suggest that what people count as valid, important and useful evidence is not consistent amongst interviewees. There appeared not to be an archetypal form or gold standard of public health evidence. Opinion differed as to what type of data are the most valuable to underpin decision-making processes and the 'horses for courses' adage appeared to hold true. The different meanings attached to the term 'evidence' are examined in the discussion chapter which questions whether or not GIS maps can be regarded as valid and reliable strands of evidence on which to ground decisions.

Moving on from perception of evidence to the process of understanding evidence, one interviewee felt that to understand the maps more clearly the denominator data in the contextual maps should be presented alongside the GIS overlays for ease of interpretation.

> *And this one again, this was low birth weights with different symbols representing very low birth weight and low birth weight over a map of total birth (contextual map) and I thought it's a bit crowded down here, there's obviously low births but then there's a lot of births down here. So I thought a better representation would be two maps, one showing the percentage of low births and one showing the percentage of very low births just side by side* (T, 13/556).

The problem of a lack of denominator data or even determining a denominator was also expressed. Without any meaningful baseline information it is difficult to attempt even a superficial level of analysis.

> *But for other things it becomes a bit harder then to decide what your denominator is. Even these industries (pointing to map on page 9), I guess that's the numbers of sites but then again does that mean anything? Should it be the numbers of people working in each industry for example or I suppose more logically in this context the land area that each industry covers so that it appears that dockyards/shipbuilding are only 3% but they actually cover 20% of the land and employ 40% of the workers. So there's always a denominator. I think interestingly, this is just off the top of my head, but I think geographic data*

> *often possibly has more problems with denominators than graphical representation for example or whatever* (N, 14/650).

This same participant also referred to denominators being a particular problem associated with point datasets:

> *And firstly you'd perhaps want a denominator using the positive samples per one hundred houses or whatever 'cause some area which has a particular problem noticed might get a lot of extra sampling so again it's a difficulty of using points, you don't know what the denominator is for those* (N, 14/672).

Again a number of participants, notably those involved in statistics and scientific data analysis, seemed to be concerned about the issue of denominators. Obviously the need for baseline information to qualify data interpretation and analysis is critical but some respondents seemed to use the absence of denominator data as an excuse not to engage with the report. Perhaps for some the scientific model with its deductive reasoning and statistically based methods still prevails over the notions of collaboration, multi-disciplinary working and partnerships to create and sustain population health.

Concerns such as the failure to take into account population density were also highlighted leading to the recognition of the balance between trying to display enough data to enable interpretation without reaching the threshold for data overload.

> *But it was the same thing, areas that had high numbers of births just did by chance have high levels of soil lead. But they're also densely populated areas* (T, 14/599).

The above comment suggests that the respondent had a clear understanding of the pitfalls of GIS data presentation but by focussing on the limitations of the data displays it is possible that she lost sight of the bigger picture and the possibilities and insights that GIS technology can offer to the public health community. Issues surrounding types of evidence, methods of collating and distilling large quantities of complex information and the grounding of decisions in robust and systematic evidence are explored further in Chapter 7.

6.3.7 The need for more than just maps for making decisions

Interviewees more experienced in GIS techniques were able to talk lucidly about the mechanisms and intricate pathways involved in producing GIS map representations. When discussing data presentation methods for use in evidenced-based decision-making, an experienced GIS user recognised that to

make robust and judicious decisions examining more than one source or branch of evidence is often necessary.

> *I think to be fair you need at least two or maybe three I'm not sure...basically to allow you to drill down because GIS even if you've got fairly small levels of geography you need to compromise between accurate depiction of the data and having a map which is easy to understand* (D, 20/957).

It became clear that to ensure a broad understanding for decision-making, maps alone are insufficient. Different strands of evidence produced from a range of contrasting methods provide a more integrated and holistic picture. In this way richer information with more depth and detail could be used to support decision-making processes. The interview discussions suggested that agencies would be willing, in theory at least, to share data and to work in a joined up way. Whether these aspirations hold true in praxis is another subject for debate and is addressed later in chapter 7.

> *For a lot of purposes and many uses this pictorial representation is the best way of doing it...I think you just need to be aware there is no one way of presenting data that gets round all of those limitations. Each one has its own quirks and limitations* (D, 21/1018).

Although useful, particularly for demonstrating the distribution and spread of data, GIS was seen as not holding all the answers when a finer level of analysis was required.

> *So this is good as an overall view of things and you could say well I want to concentrate on that dark area there can I drill down into that and you can do that with a GIS if you've got lower level data or you might just want to go in and say what those values are in which case you need a table* (D, 20/983).

Consistent between respondents, was the perception that GIS representations were a good means of gaining a feel for the data and to target direction for further exploration and examination.

6.3.8 Issues relating to report presentation

Important questions addressed were centred around the idea of communication: how does GIS communicate data and does it do so effectively? A number of participants volunteered their thoughts and suggestions on how presentation could be improved to enhance communication. In the first instance, there was a concern that some of the data might not be easily interpretable to those without a medical or epidemiological background. This led to the question of to whom the report was intended:

> *I guess if I had a criticism at all it would be that, I think it depends on how closely people look at it. Even with something like that [pointing to the map] the*

> *interpretative notes, it depends on who you are aiming it at…I think it's a difficult one to do. I mean I think the text is fine but I just wonder if people would sort of lose the will to live looking at these because there is actually a lot of information in each of these. I mean it's fine for me because I can look at them and have some notion about what it is I believe I'm seeing or taking from it but whether I mean I don't know for xxx (a local councillor), for example, there would need to be a commentary* (K, 16/794).

The above excerpt is in keeping with paternalistic models of decision-making. By suggesting that a higher level of intelligence or experience is necessary to understand the map representations fully, the accessibility of the maps is undermined. Here the issue of training is raised and with it the associated costs in terms of personnel, software and time. Several decision-makers cited training as a limitation, which is discussed in the proceeding chapter.

Aside from the issue of status and power, the respondent quoted above questions whether some aspects of the maps might disengage the audience. Following from this, quite a number of interviewees felt some of the maps were overcrowded making it difficult to come to any conclusions about the data.

> *I think sometimes we have to be careful that there's not too much going on. In terms of the specialists doing this sort of thing because we know what it means, then that's perfectly reasonable. For us to do that layering and looking at those causal indicators then doing that I think is fine. But we probably wouldn't present it in such a busy way because it just looks like too much is going on. For example you look at that (pointing to the overlay of water lead levels and deprivation) you go ough [overwhelmed]. You have to be aware of what audience you're presenting to* (J, 11/538).

Moreover, several interviewees described the issue of overcrowding as rendering data uninterpretable:

> *I looked at some of your maps and I found I couldn't always understand. I found something like this* (pointing to the overlay of IMD and water lead data) *difficult to come to a conclusion about…I wasn't sure did each point represent a sampling point?…But I thought there were so many sampling points and there were dots on top of dots and squares on top of squares. And I was thinking well I don't really know what that's telling me* (T, 12/536).

If the audience encounters problems in comprehending the map data they may disengage from the representations. It is clear that these thoughts taken with earlier comments suggest that there is a fine balance between including too little and too much data in the maps. Tufte, on the other hand, suggests that information dense data displays *"convey a spirit of qualitative depth and a sense of statistical integrity…whilst emaciated thin designs provoke suspicions about the quality of measurement and analysis"* (Tufte, 1990, p.32).

One of the most popular issues of debate revolved around the use of colour in maps. Participants were asked specifically to comment on the use of colour or shading in map making. Colour was generally seen as a positive and

powerful tool in GIS map representations. A number of interviewees did, however, recognise that colour could potentially mislead the reader if used inappropriately. The importance of making logical and intuitive decisions during the process of map making was emphasised. Some respondents perceived colour to be a useful tool, whereas others felt that it was confusing and distracting. Elements of complexity, where cloudiness and clarity are mutually exclusive, were observed in these discourses and will be drawn out further in the discussion (chapter 8).

> *I have to say that for my own personal use I don't necessarily require to have lots of colours in the map and actually I think it can be quite distracting. I think it's useful to keep to the same colour but different shades. That seems to work quite well although that obviously has difficulties if you're photocopying. Brown seems to work quite well actually. It does seem to work. Maybe that's something to think about with soil lead levels that it is sort of like the colour of soil so perhaps that is more meaningful* (M, 13/640).

Overall the response tended to be that as long as judicious use of colour was employed, then colour could be beneficial in engaging an audience and sending out an impact message.

> *Maps are shapes and colours, which even primary school children can relate to. So they're much more accessible to a multi-disciplinary, multi-agency audience. And also we've done a lot about communication in the PCT because we recognise the need to engage with so many different people with lots of different backgrounds and knowledges so in themselves they (the maps) are a metaphor for spatial differences so you don't even have to explain them. So with a, say if you comparing standardised mortality rates between areas in a table you almost have to explain that's what you're doing. But with the map you've got a metaphor already that message that says what you're doing* (W, 9/435).

On an aside, it was interesting to note that the decision-maker quoted above recognised that there is disparity in ontological perspective amongst the public health community. Due to the very nature of public health as a multidisciplinary endeavour, decision-makers come from a variety of different backgrounds and possess varied experiences, values and beliefs. Clearly this is appreciated and accounted for at least by some decision-makers within public health and maps were felt to be an appropriate vehicle to engage each of those different mindsets.

Respondents seemed to agree that colour was useful as long as it didn't prevent the audience from reading the map. There was recognition that using colour was perhaps not practical nor cost-effective in routine papers. Additionally, the issue of colour-blindness was raised, which leads on to the debate on whether GIS is truly accessible to all.

> *Yes well colours are really popular in the NHS at the minute. Everything is colour coded on a traffic light....because that's quite intuitive again isn't it? It could be quite confusing if different people producing the maps use different colours....Colour's great but the reality is they're photocopied for a meeting and they all turn grey and you can't read them* (W, 11/528).

The participant quoted above appeared to be aware of practical issues surrounding maps. In the interpretation of GIS maps, colour-blindness is a real concern, misunderstandings could easily be taken from map outputs if colours were misinterpreted. This perhaps limits, to some extent, the democracy of GIS for presentation and communication purposes.

> *I suppose if somebody were colour blind then that would be a bit more difficult...that would obviously affect how they would interpret it. I think the disadvantages can be though if you're trying to photocopy, 'cause you don't see the shading difference, you might have slightly darker if it was particularly dark but you wouldn't necessarily see the shading differences* (M, 8/350).

One respondent's account discussed an instance when a colour scheme was misinterpreted before dissemination, which illustrates the importance of intuition and tacit knowledge in reading a map:

> *...what colour bandings should I use on a thematic map because if you use the wrong ones you might end up giving the opposite impression of what you want. I found that to some extent when I was doing the work on smoking deprivation. I showed one of the members of staff one of the maps, I think she'd seen me printing it out. It just happened to be the area she lived in and she straightaway drew the opposite conclusion about where the most deprived areas were* (D, 12/557).

Furthermore, colours have different meanings depending on culture and ethnicity. For example, the Chinese associate the colour red with good fortune, money and happiness, which is in stark contrast to its associations with danger in the West. Interestingly, one interviewee felt quite strongly that colour could be used as an effective tool in map making to facilitate the communication process:

> *I think the other point I would make as well is the use of colour is extremely important in terms of the types of colours you use on the maps and I don't know whether people have done any research into that type of thing but I think it is quite interesting. A lot of people go for the traffic lights because everybody knows them and everybody knows green is good and red is dangerous and amber's not. But it could be extremely confusing* (J, 12/575).

Others were less partisan when asked to comment on the use of colour in the mapping report. Some did not feel that it was an important issue but a number of respondents drew attention to practical issues like the ability to discriminate shading on photocopies when disseminating reports to large numbers within budget constrained organisations:

> *I don't think that really matters as long as you can clearly distinguish between them – that is the problem. And often they'll look different depending on what printer you print them on. So it looks great on your screen and then you print it and you can't tell the difference and in terms of photocopying it's completely out of the window with a black and white photocopier* (HPr, 16/727).

Basically, the need for clear and straightforward map representations using easily discriminated colours was well observed.

> *The only thing I don't like is… if the shades are very like each other so if you had a pie chart and you'd used the same colour blue and if the figure was 2% and then another 2% it's very difficult to see. So you could use the same palette but indigo or green but different greens moving through* (T, 3/133).

Similarly, the issue of map symbology prompted a reaction from some participants. One contributor spoke of the difficulties in trying to discriminate between the different symbols, some of which, particularly on the lead related industries map, are rather small.

> *I find the different symbols quite difficult, actually, to decipher on a smaller scale. Although, I can see the benefits of that, because in some ways they could be quite useful. But if they are on a very small scale and they're all bunched together it's quite difficult. They don't have the same impact perhaps.* (M, 14/669)

Again, this problem arose due to an opposing constraint: the need to condense the information for display on one A4 sized map. With hindsight it may have been more useful to construct the more detailed maps on a larger scale. From these deliberations it became clear that the decisions involved in map making were a series of compromises and trade-offs. On the theme of map keys and symbology, another interviewee observed that the use of numerous abbreviations might be confusing given the diversity of the public health audience for which the report was intended.

> *And the other thing is that some of the abbreviations are known to me but they wouldn't be known. I know, for example, that this means [pointing to DWI] the Drinking Water Inspectorate and so that these are of concern [pointing to different symbols for levels above and below the DWI standard level for lead] but those aren't of concern because in terms of risk to health these are below the line* (K, 17/829).

With reference to the quotation cited above, the phrase "*below the line*" could itself be challenged in terms of who has set 'the line' and for what reasons. In terms of environmental lead levels it has been claimed by researchers in the USA that no level of lead is physiologically "safe" (Canfield *et al.*, 2003).

Another respondent proposed that it would be more convenient and practical if maps with related data needed for interpretation were included on the same page. This comment is reinforced in writings by Tufte (1990) which

emphasises the importance of local comparisons of multiple data displays on a single page to promote and enhance visual reasoning, contrast and comparison. Tufte argues that rather than focussing on changes in the 'display container' (*e.g.* graph, picture or in this case map) the reader can focus on actual changes in information.

Finally, in terms of data presentation, an interviewee raised the subject of confidentiality, warning that some individuals may employ a map to present sensitive or confidential information without realising that such data are identifiable:

> *When you've got actual numbers in a table, people think quite carefully about small numbers and disclosure issues and often suppress small numbers. There's a danger with a map thinking there's no possibility, where all you've got is a brown blob, of identifying an individual but actually in a sense it is a table and potentially you can see. With this low birth weight for example you can potentially identify an individual in a ward in a particular year with a particular birth weight....and the spatial thing may give it an extra dimension to identification. There's a slight risk that it's easy to think that a map with blobs couldn't possibly be identifiable* (N, 15/711).

Debates around confidentiality and disclosure are omnipresent on the public health agenda and are increasingly pertinent in the field of GIS where map data are easily identifiable and sensitive issues may be examined using mapping techniques. The sub-theme of data confidentiality is drawn out and unravelled further in the proceeding chapter.

6.3.9 Concerns relating to potential childhood lead exposure

Few participants volunteered to talk about the issue of childhood lead exposure explicitly. Once engaged in discussions regarding the report a small number of respondents talked either about their experience in relation to lead contamination or spoke about their thoughts and opinions relating to lead as a public health concern. One experienced GIS user expressed concerns relating to the timeliness of the data believing that it would be inappropriate to infer conclusions from data collected two decades ago. Another respondent was asked whether reading the report had changed their view of lead as a public health concern:

> *Probably not but perhaps that's my background the fact that I'm a little bit more aware than some. But I could see that it could be quite beneficial and maybe just strengthens the understanding of some of the problems around lead. It maybe just reinforces that* (M, 16/782).

It was clear that the practitioner was already mindful of the multiple sources and diverse effects of lead that act in concert in children and though the report did

not introduce anything particularly new to the debate it served to reinforce aspects of the problem that may not be fully understood by all stakeholders working in the public health sphere.

Importantly a number of interviewees did express concerns regarding the issue of childhood lead exposure despite it having been off the public health agenda nationally for some time. Moreover, there was an appreciation that contaminated land issues, relating to the legacy of the Industrial Revolution, are an important public health concern in the region.

> *I don't know about lead specifically but I think the fact of our ex industrial environment is a crucial and poorly understood factor that may be contributing to poor health in the North East. We've had one or two contaminated land issues here and I'm absolutely convinced that they're the tip of the iceberg* (P, 11/522).

One participant questioned the appropriateness of using GIS to explore the subject of childhood lead exposure due to the 'crudeness' of the technique. It was recognised that more subtle methods would be necessitated as the amounts of lead needed to invoke a physiological effect are so small (Canfield *et al.*, 2003).

> *The things that struck me were about whenever you measure something like lead you're talking about very fine detailed measurements and epidemiology and GIS are quite blunt instruments for looking at anything like that. I mean lead in the water supply would arise mainly from the pipes right at the end of the supply in people's houses. So two different houses next door to one another would have widely different results. So if your sampling strategy isn't very good or comprehensive then your maps are going to be worthless* (I, 12/588).

This comment reverberates with a commentary focussing on the health inequality angle, which picked up on the difficulties in using a superficial technique, like GIS, to address multi-layered and un-straightforward questions.

> *The interesting question to me is the Victorian housing in Jesmond [an affluent area] less likely to give off lead than the Victorian housing in Elswick [an area with a high IMD score]. Again it's a nice picture but it's open to superficial analysis really. That's a slight risk with these complex sort of questions* (N, 14/667).

The above excerpt appears to highlight a deviant case as many respondents picked up on the benefits of GIS for integrating a plethora of data to create a rich and meaningful spatial representation (see section 7.5.2, p.197 and sections 7.4.3 and 7.5.3). Complexity discourse offers some way of visualising the 'inter-relatedness' and 'embeddedness' of public health issues and GIS seems to fit well with this approach. Instead of ignoring or sidelining an issue because it 'feels' too unmanageable, complexity can serve to disentangle the

web of messy determinants so as to provide an avenue for action rather than apathy.

One interviewee made reference to the local Byker Incinerator Study (Vizard and Pless-Mulloli, 2003) and discussed the problems that emerged from this investigation, which included issues around sampling and a lack of denominators to make sense of any emerging data. The complexities implicit within the problem of childhood lead exposure were made explicit when referring to the difficulties of investigating such a thorny and multifaceted health concern.

> *With the sampling strategy, if you take one allotment and you take ten samples they vary in lead content over a factor of one thousand. So how do you sample an area the size of a city? And then the other problem was even if you find it, what does it really mean because we don't have a baseline to work from? We know that so much of the soil around most big cities is contaminated from previous industry and one of the worries was we actually found lead levels above those acceptable for food basically in some areas. But wherever we looked we suspected we would find the same. So what do you then say, for the UK if the total food production is then dangerous? It's very difficult to know what it means. So it's all about how do you sample effectively to get real data about what the level of lead is?...It's a very difficult area to look at. It's one of those issues where GIS will add something but I think when you've got the difference between epidemiological results and GIS results you've then got to do some pretty careful interpretation* (I, 13/606).

There are clear political implications around the cost of remediation versus the potential cost of doing nothing. One of the most important issues in relation to lead contamination specifically is determining where to place the cut-off threshold for levels of concern. Questions arise as to whether there is a safe limit of lead in the water/soil and is it more prudent to focus on interrupting the source, pathway receptor relation rather than a full scale clean up.

In relation to the above narrative the question could be posed as to whether the 'complicatedness' as opposed to the complexity of the issue is used as an excuse to do bury or ignore the issue. By looking to complexity science aspects of order and disorder could be identified so as not to reduce the issue to smaller more manageable parts but to understand the dynamics of the system as a whole. The respondent concluded, pragmatically, that GIS had a role when investigating such issues and could offer a different dimension to the debate without holding all the solutions.

The complex nature of public health policy making was referred to indirectly when discussing the childhood lead exposure concern. There was an apparent contradiction in information to advise the public: lead contamination in

soils may affect allotment grown vegetables which would conflict with omnipresent healthy eating messages, including the five a day programme.

> *And some of the levels of contaminants that have been found, they are definitely borderline so I think having a better understanding of the issue of environment and sense of possible carcinogens or possible poisons that actually are contributing to poor health is very, very important and needs to be done very, very carefully because quite often the roots of how people are ingesting the stuff is through their allotments. And half the time you feel like saying well we don't want to stop people digging their allotments.* (P, 11/526).

The 2005 government public health white paper 'Making Choices' encouraged public health practitioners to support individuals in making healthy choices by offering them alternatives and disseminating information appropriately but what it fails to address is the challenge to health workers if coherent, sound and reliable information are unavailable.

The participants who did engage in discussions on the case subject, childhood lead exposure, seemed to understand the underlying difficulties surrounding the issue. They acknowledged that there were no easy solutions and one of the most important outcomes of the study was to return the issue of childhood lead exposure to current discourse, thereby opening up a dialogue and making practitioners aware that this issue has not disappeared despite its absence from the public health agenda. Looking through the complexity window it was clear that some decision-makers are aware and fully engaged with the dynamics and intricacies of contemporary health issues. Instead of aiming for simple solutions and clarity in their practice, there is an understanding and acceptance of the messy real world situation where undercurrents of order and disorder co-exist.

6.3.10 Further avenues for investigation

Several respondents were helpful in suggesting direction for developing the project further. One participant pointed to the potential for further exploration of the datasets through overlay analysis:

> *They all seem very clear to me. I suppose when you were talking about layering maps so that you can build up complex information into one image. Obviously that's happened to some extent with some of these. I don't know whether that can be developed even further* (P, 9/399).

This assertion was reinforced by a second interviewee who believed that a focus on overlay analysis could lead to further insight.

> *Obviously that takes a bit more time but superimposing them on top of each other and you could perhaps even build up so you've got your full amount* (M, 16/756).

It was recommended that separate smaller maps could be used that were more amenable to being superimposed in an attempt to look for patterns or correlations.

> *Yes maybe, especially when you're able to put them over each other. And maybe that's something to consider when setting up maps, sometimes it's a bit of trial and error to look to see how it presents really* (M, 15/724).

Equally, one respondent reinforced the value of qualitative research to unpick and unravel the anecdotal evidence from both professionals and lay individuals about lead exposure and a possible association between industrial lead and environmental contamination.

> *The other thing that might be worth doing is some qualitative work, interviews; maybe with health professionals or maybe just with people living in those areas and if you're coming to the point of view that there is an association between lead and the industrial past and educational attainment now there may be questions that you can ask with those groups that could back up that case or not as the case may be* (G, 16/693).

The interviewee highlighted the added value of learning from the people closest to the issue and building up meaning through dialogue and discussion. Such comments were encouraging as it seemed clear that practitioners acknowledged the need for public health research that goes beyond basic and narrow epidemiological models rooted in the positivistic approach. There was awareness that multi-disciplinary and partnership approaches were required to allow a range of evidence to be integrated.

6.3.11 Discussion of key findings regarding participant engagement with the mapping report

Generally the response to the report was positive and constructive. Only one participant was negative and quite cynical about the potential for GIS mapping in decision-making pathways. It was clear that the report could benefit from further iterations although there was an intention, when the report was constructed, to illustrate some of the possible shortcomings of GIS maps as evidence and to this end the mapping report was successful. As well as stimulating dialogue and debate around the value of maps as evidence, the report also served to highlight the benefits and limitations of GIS technologies in public health practice. The responses of participants to the report tended to correspond well with the researcher's own experience using GIS: issues around map boundaries, judicious display of choropleth maps and inclusion of

denominator data were flagged up as areas of concern in the map making process and revisited during interview discussions.

While some contributors (particularly those representing agencies with a well defined health remit) were happy to comment on the explicit problem of lead contamination, others were more reluctant and either avoided the subject by focussing on issues around report presentation or stated that they were not in a position to answer the questions. In fairness when individuals were approached to be interviewed they were assured that the discussions would centre on the value of GIS in public health rather than their thoughts, opinions and beliefs around the issue of childhood lead exposure. A significant outcome of the map-focussed discussions was to reintroduce environmental lead contamination and potential population exposure back onto the public health agenda.

Elements of complex systems discourse were observed in the discussions. Public health is neither a linear nor a rigid and monolithic discipline, which as a system creates its own complexity pathways. Component parts are nested within the system and linked by a multiplicity of subtle and dynamic inter-connections. From the discussions it was clear that decision-makers - sub-consciously at least - understand the complexities of public health practice. In addition, they recognise that there is a need to work together across community, environment and clinical disciplines. Such an approach is not simple and straightforward, the work is messy, the dialogue is confusing and the problems are contentious. As such a clear and sound theoretical insight into these issues and tensions is necessary to drive progress and to achieve practical results. The following chapter examines the thoughts, perceptions and opinions of public health decision-makers on (i) the value of GIS technologies within public health; (ii) the status of maps as strands of evidence for underpinning decisions and (iii) the potential for GIS to enable data sharing and collaboration between organisations.

"All political thinking for years past has been vitiated in the same way. People can foresee the future only when it coincides with their own wishes, and the most grossly obvious facts can be ignored when they are unwelcome"

(George Orwell, 1945).

Chapter 7: GIS technologies and maps as evidence

7.1 Introduction

This chapter continues with the findings from the interview component of the study, which addressed study objectives 3 and 4:

- To conduct a series of semi-structured interviews with decision-makers in eight agencies whose work impacts on the public's health.
- Through analysis of transcripts explore the value and potential contribution of GIS maps to the evidence base for public health decision-making.

A number of quantitative studies (mostly involving survey approaches) have been undertaken in the past ten years to assess the uptake of GIS in the health sector (Cockings *et al.*, 2004; Higgs and Gould, 2001) but understanding of how public health decision-makers value GIS technologies and maps as evidence remains limited. By conducting in-depth interviews with key decision-makers the study examines and explores how public health practitioners perceive GIS as a technology, appraise map outputs and whether or not they believe there is a place for GIS in decision-making processes.

An overview of the qualitative element of the case is presented followed by an in-depth exploration of the emergent themes. As well as enabling a comprehensive critique of the GIS toolbox, and an examination of the advantages and limitations of maps as 'evidence', the meaning of maps to public health practitioners is explored. The content of this chapter is mainly descriptive but by employing the framework derived from chapters 3 and 4 (figure 4.2) and drawing on the central tenets of complexity science some theoretical insights are developed. A deeper and more conceptual understanding of the key issues raised by participants is presented in the Discussion, chapter 8. At the end of each section the most significant issues are summarised and the links to complexity discourse are highlighted.

7.2 Emergent key themes

The three central constructs determined in the theoretical framework for the study were applied and used to shape analytical data dredging: GIS data origins, GIS data status, and data application. The iterative process of thematic analysis saw the emergence of a fourth construct: data sharing, which is

collectively summarised as data reciprocity. The importance of the public health context is captured in the theme of data origins. This construct covers issues relating to how different individuals see the world and how they measure phenomena within it; their ontological and epistemological stance. By unpicking such issues implicit biases and assumptions can be uncovered to cast light on how decision-makers react to and make use of different strands of evidence. It could be postulated that decision-makers in the environmental sphere engage with GIS data representations differently to those who work in organisations with a stronger social or health related function. This proposition was tested and comparisons across the various agency types were made.

Data status explores issues relating to how public health decision-makers value GIS data and captures concerns such as misunderstandings, misinterpretations and misuse of spatial data. The common place adage that 'statistics have the potential to lie' is explored in relation to GIS. The theme of data application examines how GIS data are used in practice and whether or not there is a place for such data in evidence-based public health practice. Examples of GIS based decision-making are appraised and the limitations as well as the strengths of such endeavours are highlighted. It is well accepted that collaboration is a central tenet of contemporary public health. The theme of data reciprocity captures the notion of interagency working and collaboration, The debate around data reciprocity therefore attempts to tease out how evidence-based decisions are made across and between agencies and whether or not GIS representations can be used in processes that support or underpin partnership working.

The key themes are laid out in figure 7.1, which demonstrates the various links, junctures and interconnections between the central domains and sub-domains that emerged from the interview findings. The diagram builds on the notion of complexity as a sense-making tool in analysis and theory building. More in depth analyses led to the construction of discourses to embed the emergent themes: namely: data origins (Ontological Discourse), status (Power Discourse), application (Functionality Discourse) and reciprocity (Collaboration Discourse). To contextualise the debate some discussion on the modern meaning of public health is presented before exploring each discourse and its associated thematic constructs.

7.3 Meanings of public health

The interviews were designed to explore how participants viewed public health and to examine how the elements of belief, experience and knowledge interacted in their decision-making processes. The definition of public health as "*the science and art of preventing disease, prolonging life and promoting health through the organised efforts of society*" (Acheson, 1998) is commonly cited in the contemporary literature and by modern public health practitioners who recognise the boundaries of traditional biomedicine. MacKian *et al.* (2003) suggests that definitions of public health as a static and mechanistic phenomenon are incongruent with modern understandings of health as a dynamic, fluid and boundary-less phenomenon. Overall the responses gathered were commensurate with this organic and mercurial interpretation of public health.

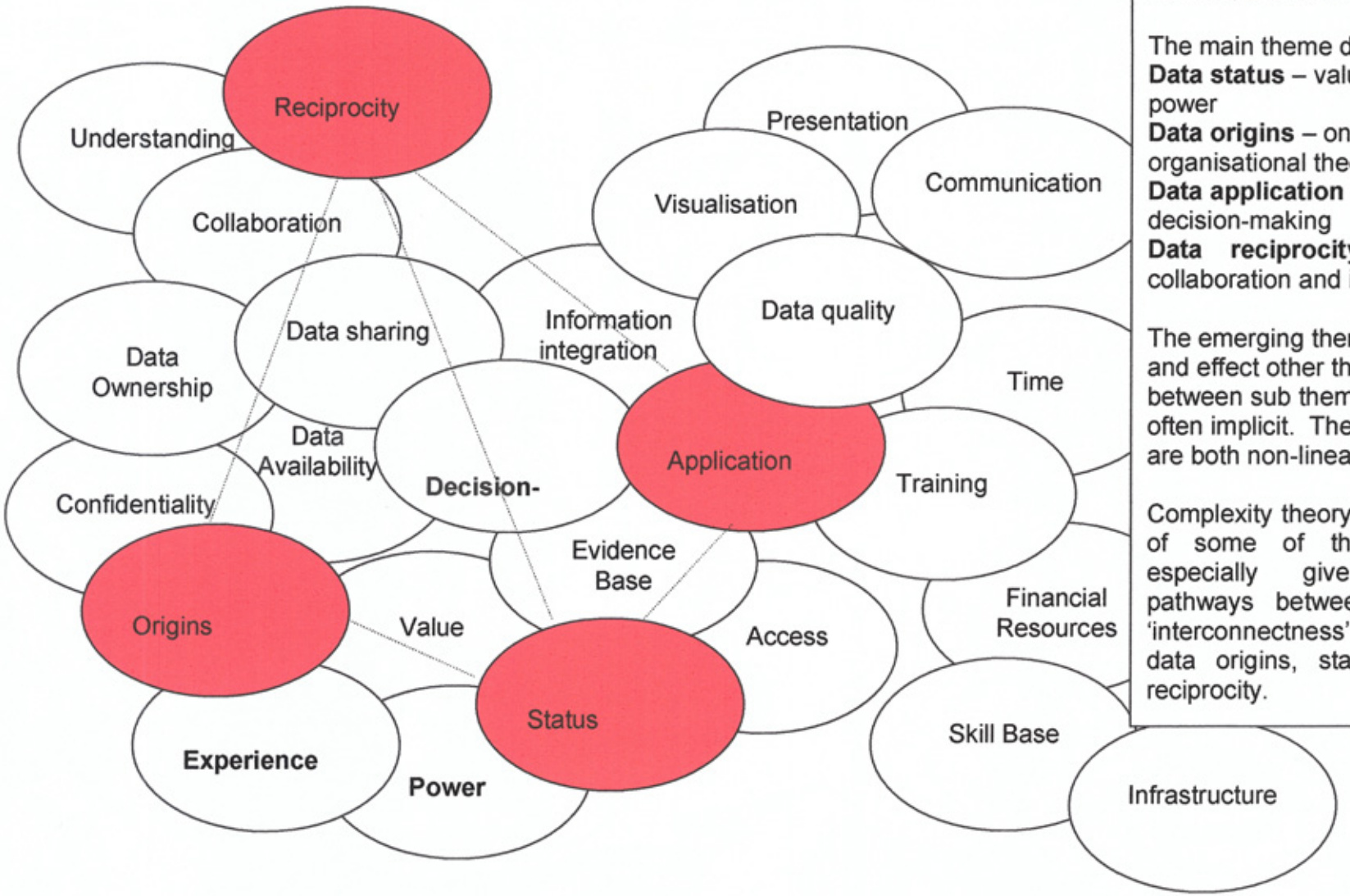
Generally respondents saw public health as a "*broad church*" (H, 11/515), a rather nebulous notion that was difficult to articulate and define. Most respondents clearly appreciated that the central focus was on populations rather than individuals.

> *I mean I think public health is quite hard anyway to grasp. It's quite a difficult discipline to understand if you're talking about risk, you're talking about a generalised statistical risk and not a risk to every person. That's quite difficult* (H, 6/253).

The quotation above refers to the prevention paradox (Rose, 1985), a significant construct in public health discourse, which explains the tension between a focus on the aggregate rather than the individual in terms of preventative initiatives. Public health was perceived to be an overarching and multifaceted issue that should not merely be thought of as a National Health Service or biomedical concern.

> *It's about seeing public health not as a separate issue and not as a health service issue but as something, which is important across just about everything that goes on.* (D, 1/29).

Figure 7.1: A non-hierarchical map of the key themes emerging from preliminary analysis



The diagram displays the interrelations between themes involving overlapping themes, outliers & satellite themes:

The main theme domains include:
Data status – value, explanations of power
Data origins – ontology, epistemology, organisational theory
Data application – evidence-based decision-making
Data reciprocity – data sharing, collaboration and interagency working

The emerging themes are affected by and effect other themes. The relations between sub themes are subtle and often implicit. The evolving processes are both non-linear and dynamic.

Complexity theory helps to make sense of some of the emergent issues especially given the reciprocal pathways between themes and the 'interconnectness' of the key areas of data origins, status, application and reciprocity.

Without explicitly defining public health as complex, participants grasped the cross cutting nature of public health and the inter-relationships that affect and are effected by other non-health issues. Borrowing from complexity discourse there are straightforward and linear systems inextricably linked to disordered and complicated processes. On one level public health is simple, for example its objectives to prevent ill health and promote a state of physical, mental and spiritual well being can be defined relatively easily but on another level public health is messy, disordered and rife with contradictions (exemplified by the nanny state and personal choice conundrum). These contradictions are inherent in many public health concerns as evidenced below in relation to economic well-being versus environmental well being and healthy eating versus minimising exposure to environmental contaminants:

> *Sometimes the world works in ways, for example increased economic well being decreases public transport use, it has a natural tendency to do that yet the region has targets for increasing public transport use. So there are some very hard things (H, 9/426).*

> *We've had one or two contaminated land issues here and I'm absolutely convinced that they're the tip of the iceberg. And half the time you feel like saying well we don't want to stop people digging their allotments. At the same time we could do with understanding better if there are health hazards (P, 11/524).*

The complexity of contemporary public health problems can be visualised in 'wicked' issues such as childhood obesity where dynamic variables such as health inequality issues (socio-economic status, single parenting and food deserts) are exacerbated by social factors such as decreased outside play and the boom of computer game technologies (Covic, Roufeil & Dziuraweic, 2007; Robinson & Sirard, 2005). Similarly, the issue of childhood lead exposure, considered in the mapping report, is multi-faceted and nested within larger social issues.

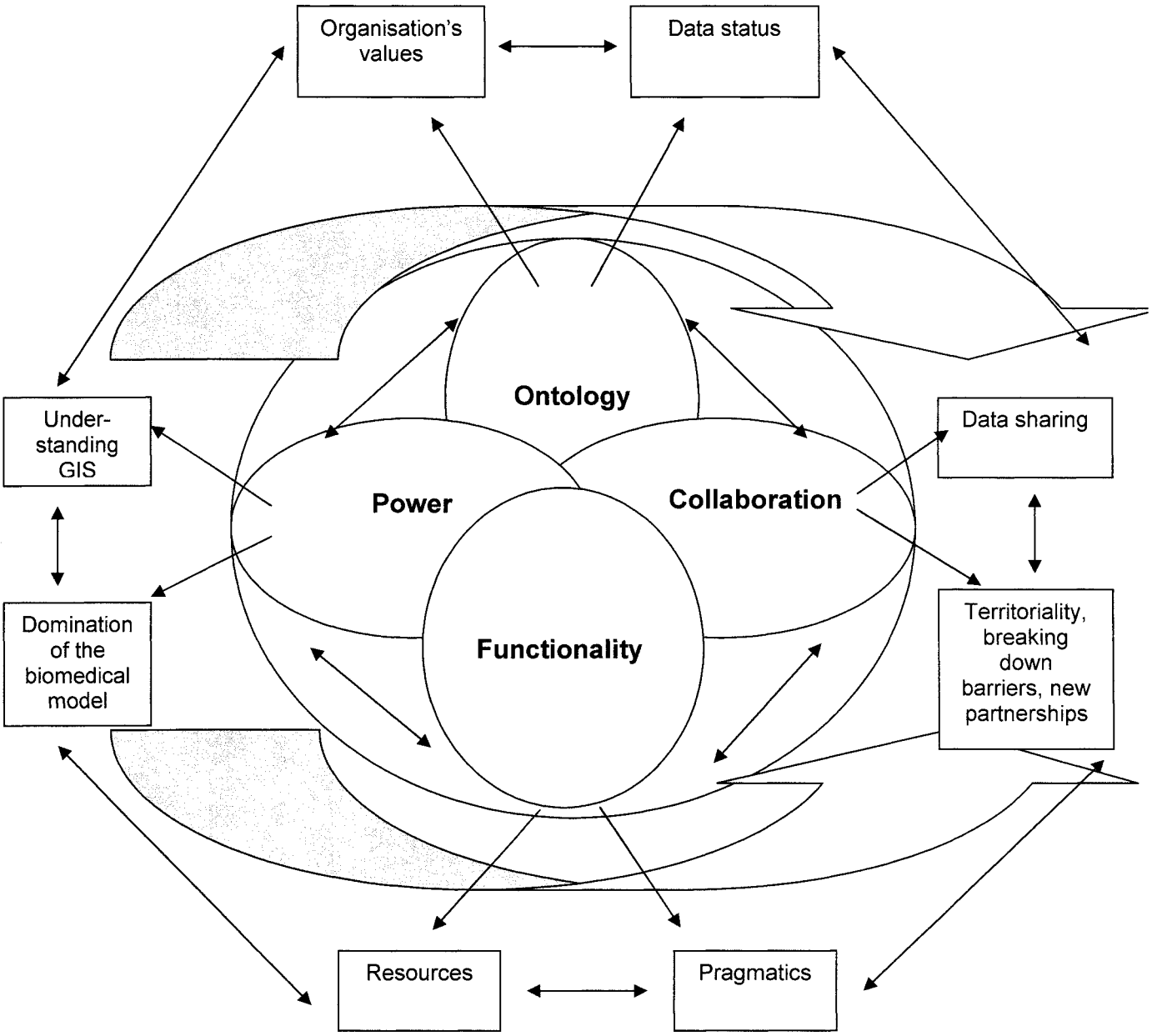
Lead is ubiquitous in the environment (Thornton, Rautiu & Brush, 2001) yet it is those children living in disadvantaged circumstances who are most at risk: those who are exposed to lead through old paint on house surfaces in need of renovation, contaminated soil (deprived areas tend to have more sites of former lead associated industries[12] or current Integrated Pollution Prevention Control (IPPC) sites in Newcastle) and water (houses where leaded pipes have

[12] Industries producing high levels of lead contamination include: lead refining and smelting; battery manufacture; recycling; paint production plants; demolition and lead mining (Spivey, 2007).

not been replaced). Risk is also heightened in children who are malnourished (American Academy of Paediatricians, 2005) and there is concern that infants being bottle fed using formula milk made up with water from leaded pipes might be disproportionately affected. Interactions between aspects of lead exposure are non-linear and a change in any one exposure pathway is likely to result in a much larger change to the exposure profile overall.

In summary, the boundaries within public health and between public health and other disciplines were seen to be limiting. There was a clear recognition that public health was not a discrete issue and that joined up thinking and sharing of skills, intelligence and learning were required to promote public health. After re-analysis of the emergent themes in relation to current understandings of what public health means to those working in the field, themes were categorised into four families or groups, referred to here as discourses (the Ontological, Power, Functionality and Collaboration Discourses). These groupings were felt to reflect the core tenets of public health whilst also embracing the conceptual framework (data origins, data status, data application and data reciprocity), which emerged from initial analyses. The inter-relations between each of the discourses are captured in figure 7.2.

Figure 7.2: The inter-relationships between discourses in public health decision-making



7.4 Ontological discourses (data origins)

Ontology is defined as the study of the nature of being or existence (Collins, 1998). In other words, ontology is concerned with how individuals make sense of reality, the patterns they perceive and the meanings they attach to those experiences (Stacey, 2007). Reed and Harvey (1992, p.358) suggest that "*philosophical ontologies deduce the outlines of the real world by examining the a priori structures of scientific knowledge*". While ontologies define the boundaries of reality, the mapping of the internal surface

of an issue, its contours and landscape, lies with the researcher or scientist. The first prompts used in the discussions were designed to enable the interviewer to get a sense of how participants 'saw' reality and to unpick their understandings and assumptions relating to the public health world. . Questions were asked about their thoughts regarding evidence-based practice in the public health context in an attempt to understand their epistemological stance (or their value judgements relating to the way in which knowledge is assimilated).

It was important to consider questions relating to the participants such as:

- how do they perceive the world?
- how do they understand public health?
- what types of evidence do they value?
- what methods do they believe should be used to gather public health evidence?

The responses to these questions were fed into analysis but were also useful to target and guide the interview questions.

7.4.1 Values: interpretations of evidence-based practice (EBP)

Values are not simple linear quotients; rather they are affected by a multiplicity of influences, which include organisational policies, initiatives and directions but also experience, beliefs and knowledge (both tacit and explicit forms). This alinearity and irreducibility is a hallmark of complex adaptive systems and features throughout the discourses. When asked to give views on evidence-based decision-making one participant, drawing on his experiences, replied:

> *I'd say that evidence-based decision-making tends to refer to: is there evidence prepared in accordance to the hierarchy of evidence, i.e. evidence that you can be confident in, in relation to the effectiveness or cost-effectiveness of interventions? I think an area of confusion has been that there's another interpretation of evidence-based decision-making which is to do with the robustness of our understanding of need and the way that we monitor success in terms of changes* (P, 2/78).

Another interviewee emphasised the importance of an evidence-base from an organisational perspective:

> *We're a government based organisation and we make decisions based on the evidence. We don't just fancy the idea...And evidence-based goes hand in hand with risk-based. We don't use the words evidence-based that much but you'll see risk-based the whole way through. It's permeated with risk-based* (B, 4/168).

In the complexity domain, decision-making is thought of as an open system, which evolves and adapts in the presence of changing internal and environmental triggers. Respondents were quick to recognise the intricacies, nuances and difficulties of the decision-making process and tended to see evidence-based policy and practice as a paradigmatic 'way of doing' but one that could not be strictly adhered to in the real world. The pragmatic need for sound and robust evidence to ground and underpin decisions was understood but in the same way respondents emphasised the presence of competing drivers such as local constraints including finance, resources and a suitable infrastructure for implementation.

> *It's a complex mixture isn't it? So what are the national drivers, what are the regional drivers, the local drivers, what are the evidence base drivers, where's the resource coming from, what are the financial incentives and drivers? It's a whole hotch potch and decision-making isn't only about putting the best evidence into practice, in a pure world that would be ideal but it isn't actually how it happens. We have to be pragmatic about that because we live in the real world* (K, 2/70).

Here the narrative clearly acknowledges (albeit superficially) the complexity of decision-making and the 'embeddedness' of these processes within the local, regional and national contexts.

Complex systems theory highlights the significance of the interactions between components rather than simply the component parts themselves. Clearly, when the interviewee refers to "*best evidence*" this is dependent upon the particular issue, the context in which it is embedded and the types of questions to be answered as well as the outputs expected. The value particular decision-makers attach to different branches of evidence tends to reflect his or her ideological stance. For example, when considering strategies to understand and deal with the escalating incidence of methicillin resistant *Staphylococcus aureus* (MRSA), *Clostridium difficile* and other nosocomial infections individuals trained within the biomedical paradigm might be keen to collate evidence relating to incidence and prevalence in order to define the problem statistically. Conversely, those familiar with sociological ways of knowing might be more interested in conducting interviews with hospital staff, family members and patients to understand the 'how' and 'why questions and to collect experiential evidence which might help to drive forward solutions. As Robinson and Sirard (2005) suggest public health research should adopt a more 'solution orientated' approach rather than problem focussed strategies, which can be constrictive and self-limiting.

A common theme throughout the interviews was the pivotal role of evidence in decision-making and the utter dependency of the process on decisions being grounded in the best-substantiated evidence available. The paucity of good quality evidence (valid, reliable, robust, complete, appropriate and timely) was highlighted and the reality of having to make 'best use' of the 'best evidence' that is available in practice was underlined by participants:

> *Quite often the evidence we do use might be the least robust of all but only because that's all we've got* (D, 6/262).

Many observed the difference between data and information. The question is posed, therefore, as to whether one of the most important and significant functions of GIS software is to support the pathway of converting data into information and knowledge?

> *There are two sorts of evidence which you use to make a decision. The first is information about what is going on and there's a big difference between information and data which is not always appreciated so you need to have data available which is processed in a way to give you information. And there are all sorts of issues there about data quality* (L, 1/15).

> *The second sort of evidence you need to make good decisions is evidence of what works or what's important. And so for example, the evidence base is probably better than it appears but it's often a point of access* (L, 1/33).

Seemingly there are issues around availability and access to datasets. The existence of gatekeepers and the lengthy and often prohibitive ethics procedures involved can act as significant barriers to data access and is discussed in the following section.

7.4.2 The hierarchy of evidence

With no exceptions, participants felt that GIS was a tool that is very much data dependent and its use should reflect the question of interest (Pettricrew and Roberts, 2003). Rather than fitting into the hierarchy of evidence like other quasi-experimental methods, GIS was seen to be a tool for assimilating evidence rather than gathering data per se. GIS was not viewed as a new method and the feeling was that it assisted rather than directed research endeavours.

> *I don't think I'd ever thought about using it in that sort of hierarchy really... It's a tool rather than a research method isn't it?* (M, 10/469).

It became apparent that the majority of participants felt that GIS maps did not fit with the hierarchy of evidence. When asked to comment on this issue one NHS based respondent responded:

> *That's very difficult because I try and avoid the hierarchy of evidence when it comes in public health because it doesn't fit very well for us. I suppose for me it would. It's generally observational data that would sit alongside traditional epidemiology as an alternative view of what the evidence shows* (I, 7/322).

There seemed to be agreement that GIS could be used to add another perspective to the overall view of a public health issue but there was more value in it being used to address a question or concern that had an obvious spatial dimension.

> *That's quite an interesting point whether you're trying to get the same information with a different method or you're actually looking at something completely different. And my view is that it is different. So there is value in doing both...The issue for us is really whether is the added value worth it, especially given the difficulty of accessing the service* (I, 7/330).

It is clear that the NHS respondent sees GIS as a tool with its own distinct role in representing evidence. Several respondents referred to the old adage "*garbage in, garbage out*" or *"rubbish in, rubbish out".*

> *I get freakish about data. You know the garbage in, garbage out and all sorts of stuff and you could say well if you don't have good data then you can't do the analysis but unless, it goes back to what I was saying earlier about sharing data across boundaries, agencies and so on. If you don't pay sufficient attention to the suitability, fitness for use, the quality, the dual referencing standards and so on then you'll end up with deeply dodgy data* (V, 8/368).

All participants in the study - inclusive of those with little previous experience using GIS packages or GIS outputs - recognised the dependency of GIS on high quality data.

> *I think there is huge variation in good quality data around the NHS. Where there's payments been made then inevitably the data quality is good, where there aren't payments required then maybe it's not as good. I'm thinking particularly of independent contractors such as GPs and such like (M, 5/223).*

Furthermore, there was a common and recurring concern about the actual availability of good quality data.

> *There's a limited number of useful datasets around. So to be useful in itself you've got to have high quality datasets. So they have to be timely, reliable, repeatable, complete all of those criteria. And there are very few like that* (W, 6/295).

In some cases there may be false understandings that data are available when in fact the data described are out of date, incomplete, irrelevant or biased. In other cases there may be no data - of any quality - in existence at all. This can often give rise to situations where inappropriate data are used to answer a question giving spurious results with costly consequences.

The theme of budgets emerged from the discussions and there was a feeling that the availability of good quality data correlated with areas of

investment which tended to be those with political clout (and popularity in the media) such as smoking cessation strategies, programmes to reduce obesity and improve diet and support to encourage sensible drinking (Department of Health, 2004).

7.4.3 Discussion of ontological debates

The introductory discussions yielded a rich and diverse range of responses demonstrating multiple and related ontological and epistemological perspectives. Decision-makers in the environment area tend to use GIS on a day to day basis as a data storage and visualisation facility. Conversely, NHS decision-makers saw GIS as an analytical tool with un-harnessed power that had the potential to be used more often within the NHS setting. A number of NHS practitioners were keen to relate uses of GIS to the positivist and deductive paradigm – perhaps because this was the epistemological position with which they were most comfortable.

There seemed to be an explicit need amongst some respondents to equate GIS to the scientific programme thereby endorsing the use of GIS in deductive analysis and the search for an absolute truth. Practitioners in all sectors, including health, community and environment, valued the presentation and communication properties of GIS packages. In particular a number of respondents saw value in the use of GIS for converting raw data into useable information and knowledge (the data to knowledge pathway). GIS was viewed, principally, as an effective means of integrating data for display as opposed to storing or analysing data.

The hierarchy of evidence was not seen to be a useful framework in which to consider GIS evidence. The notion of a hierarchy is often misplaced in the real world where evidence may be limited and what matters is what works to address the question of interest in real time and often in less than ideal circumstances. Any attempt to attribute a grading system to GIS evidence would effectively undermine its value as a research tool. Likewise, in complexity theory the notion of applying external forces to control a system is largely untenable (Kernick, 2006). Within a complex adaptive system, behaviour emerges from the fine and delicately balanced interactions between components. The system is unreceptive to any formal means of control and any attempt to enforce order can result in unpredictable patterns of behaviour.

In response to the prompt about evidence hierarchies several decision-makers were keen to emphasise that such a framework would be redundant in practice because GIS was not a method of research but rather a tool for analysis and presentation. Responses were shaped by the underlying mindset of the individual interviewed. There are no right or wrong answers regarding what GIS is: an analytical toolbox, a device for presentation; a means of communication; a research paradigm (in the GIS world) or even a discipline in its own right. Subsequent responses were, therefore, in line with how individuals 'saw' GIS and how they framed its qualities and limitations with respect to their work and practice.

The concept of evidence-based practice was well understood but participants expressed some concerns about the pragmatics of being able to apply this paradigm to all scenarios in reality where the constraints of time, resources, training are omnipresent. The drive towards evidence-based practice is high on the agenda in almost all branches of public health, although it may be framed using different terminology (for example within the Environment Agency the language was about risk). Nonetheless the core principles of accountability, integrity and judicious use of data are the same. There was a strong consensus that the use of GIS was dependent on the availability of good quality data. Many respondents referred to the notion of 'garbage in, garbage out' to explain that GIS has no power to make sense of nonsensical data. This is obviously an exemplar for all methods of analytical enquiry.

7. 5 Discourses of power (data status)

A number of themes from the interview conversations touched on the overarching notion of power. Aspects of power were seen in how respondents reacted to and interacted with the GIS mapping report. Drawing on Foucault's (1972) commonly cited notion of 'knowledge as power', several interviewees recognised the 'power of GIS' to add to their existing knowledge base using visual models which can tell a slightly different story. At another level there was recognition that GIS was not neutral and maps could be misunderstood or misinterpreted. Moreover, participants were aware that there was some potential for maps to be manipulated to either support or negate a particular standpoint or view. From a complexity stance the idea of a patriarchal model of

knowing is refuted. Undeniably anti-positivist, advocates of complexity science argue that knowledge should be shared and should not be the domain of those holding positions of power. Discourses of power can be understood at three different levels or as nested systems, (i) at the data level; (ii) at the organisational level (power within agencies) and (iii) at the (power between organisations). Each of these domains of power will now be discussed.

7.5.1 The power of GIS data

At the data level, respondents recognised the importance of having access to meaningful information believing that in doing so, more robust decisions could be made:

> *Depending on what your need is...the best informed decision could be made by having access to a lot of different information sources in order to give a better picture for those who are making the decision....It helps justify what you are aiming to do. Or you could take the converse view and say well we don't need to put any resource into this area at all because there is no data to back it up from a number of disparate sources. You might get a shock and find out that there is data to back it up that helps inform the decision-making process* (F, 14/686).

Moreover it was recognised that by drawing together data to increase the knowledge base decision-makers could be given access to the evidence to justify a potentially contentious decision.

> *And I think also for some politicians again in the past they were worried that if they put X resources into a particular place they would be accused of doing it for political gain. It's "oh that's a marginal ward no wonder you put money there"* (U, 9/405).

Here, the respondent refers to a ward being marginal, in terms of number of votes. Through GIS, decision-makers can harness spatial data (the raw form of information and knowledge) to affect the economy of power and make political gain.

> *I mean they say that information is power, knowledge is power. And the more you have available, the more powerful your argument can be one way or the other. You might not be the information holder but you might want to use that information. But without that information being linked to this information, perhaps neither is of any use to anyone* (F, 14/693).

These comments suggest that GIS maps may represent a valid form of evidence to support political decision-making processes. A further example of how data can be used to conserve power and protect an organisational policy is seen in a North East Utility Agency's approach to water sampling. The results of random testing for heavy metals are available in the public domain, however when a particular site exceeds the Drinking Water Inspectorate limit for lead,

follow up data are not made public. Whether or not these data are deliberately withheld, through collusion with others in authority, is subject to debate. The policy is certainly questionable and is reflective of the way in which individuals and organisations perceive how retention of information equates to power. Ideas relating to equity and distribution of power parallel the core concepts of complexity thinking, which is fundamentally against the traditional patriarchal system of positivism.

7.5.2 Organisational stance

To address issues around the status of GIS in organisations, involved directly or indirectly in public health, questions regarding the value of GIS technologies were posed and followed up with discussions about the value of maps as evidence. Respondents were realists overall. The following quote demonstrates how the question of whether or not GIS should be employed is based on weighing up whether the output is worth the effort invested:

> *I do value GIS. My view is that it is one of a range of tools that we have to look at public health and epidemiological problems and in my experience you get different information from GIS than you do from epidemiology. And so there is an added value but it comes down to whether that added value is worth the additional investment at the time because GIS for us is marginally, the marginal cost for adding GIS to what we do is high because we don't have it as a routinely available service. But I have actually published a couple of papers myself involving GIS* (I, 4/153).

Regarding the value of GIS as a suite of technologies one participant working in the field of child health commented:

> *I think it's very useful. I think what lets it down really is the fact that if you don't have good quality data to populate the maps, then you're not really able to use the process very well. And it's very much about if you put naff data in, you get naff data out. So it can be very valuable if you've got good quality data and you're able to populate the maps adequately with that data. But if you don't have good quality data in the first place, it doesn't matter how pretty you make the maps it just won't work. It needs to be good quality data that you're able to access* (M, 3/130).

The practitioner appears to recognise the critical importance of high quality data to yield meaningful results. Data quality was the most frequently cited theme emerging from the interviews, which was rather telling about senior decision-makers familiarity with the precepts of GIS science. Despite having little first hand experience of GIS, respondents tended to have well developed knowledge of mapping concepts and GIS functions.

Moving on to issues around how participants *felt* about GIS technologies a general positive response was garnered. In most instances respondents

believed GIS technologies were valuable and depending on the problem to be tackled GIS was seen to be a useful tool.

> *I suppose it's quite highly valued.....We do produce a lot of data and that all needs to somehow get out there* (B,13/577).

There appeared to be consensus that GIS is a *tool* available and at the disposal of most practitioners. Generally GIS could be accessed by participants but in the majority of cases due to the decision-making responsibilities and seniority of participants interviewed they were seldom involved in the direct application of GIS software. Instead their role was in assessing and appraising the evidence produced using GIS or utilising the outputs in presentations or sometimes in decision-making:

> *To me it's just another tool to help understand the evidence. The evidence is there but you just don't necessarily make sense of it and mapping helps to make sense of the evidence* (T, 17/778).

> *But certainly it's just one tool of many in the decision-making process in whatever field that happens to be* (E, 7/329).

Participants seemed to appreciate that GIS like any other instrument or tool has its own range of shortcomings and limitations. It is neither infallible nor a panacea for public health decision-making practice.

> *I think it's potentially very useful but it's limited by these constraints, some of which are practical, some of which are political* (L, 4/153).

> *It's not magic but...* (N, 11/516)

> *I think they're powerful tools in public health discourse but as evidence I think that was just a bit too strong. They're not the evidence are they? It's the data that goes in. They're just a tool. Well they can be an analytical tool but in terms of discourse they're a presentation tool* (W,11/513).

> *I think that its ability to integrate, analyse and then communicate and I think that in those it's got so many that it is truly unique. At the end of the day you know you can't have the tail wagging the dog, it is an analytical tool. In that respect it would be wrong to make it any more of a big deal than Word for Windows or Excel or SPSS or what have you. You don't want to get overly obsessed* (V, 8/359).

Other participants urged caution with respect to over use and over reliance on GIS technologies and their associated cartographic functions. As other respondents have debated there is a concern that GIS is seen as a machine for producing 'pretty pictures' with little relevance, meaning and sympathy for GIS science. In effect, this could be referred to as misuse of GIS.

> *Some people can get carried away with producing maps and the science can get lost. There's also a tendency for over reliance on the maps* (C, 2/50).

By some, GIS was seen to be powerful but only in limited circumstances:

> *It goes back to this problem which is if it was more useable it would be more valuable. And I think the GIS, I think I value it as a very powerful tool in very limited circumstances* (L, 3/111).

This comment begs the question 'what would make it more useable, having specialised GIS experts or making the tool available to all?' The issue is addressed later in the chapter when several individuals, especially those working in NHS or Department of Health led organisations debate this particular point.

The idea of choosing the most appropriate tool for the problem, issue or question to be addressed was a common theme that pervaded discussions. Yet again, individuals referred back to the crux of the issue, the real underlying driver that is data quality.

> *I think it's probably also a tool that may be more valuable in time if better data is ever available* (L, 4/117).

> *You tend to find that the software isn't the limitation, the limitation is in the data* (G, 6/269).

> *Yes and that's one of the biggest problems with GIS is getting the denominator data, getting the data for the relevant geography* (T, 13/570).

This pre-occupation with data quality and the need to apply strict standards of scrutiny and rigour seemed to be specific to GIS data and not to other forms of data representation. Perhaps the familiarity of traditional types of data displays (such as graphs, pie charts and chi square tests) means that they are more readily accepted and not subject to such rigorous critique.

For some the value of GIS lay in its ability to deal with complex information in a way that might facilitate understanding or make issues real. By simplifying issues GIS has the capacity to engage individuals who may not relate to other means of presenting data. This leads to the question: if GIS can engage an audience can it at the same time disengage another? Issues around understanding and misunderstandings are taken up later in the chapter when thinking about the use of maps as evidence.

> *For me I think it's very useful in terms of presenting complex information to a diverse audience which is mixed together because people recognise the map. They know the map and they know usually where they sit on the map. They know where their village is or whatever. It just simplifies it and makes it real because of the visual impact of it* (J, 6/250).

The metaphysical notion of 'realities' and 'making things real' was vocalised by several respondents in the study. Questions were raised as to what is real and what is reality within a complex world and whose reality if this

referring to? It was clear from initial discussions that interview contributors were coming from quite disparate positions and thus visualised GIS technologies and GIS data representations according to their own world-view. Some insight was gleaned into how GIS impacts on realities. A number of decision-makers believed that GIS had the capacity to construct reality (see quote below), whereas for others, issues around data misrepresentation or erroneous application (refer to section 7.4.6) highlighted the power of GIS to distort reality. Readers are reminded that the issue of data distortion is not just specific to GIS data but to all data representations as suggested in the following excerpt:

> *But one of the things I find with maps is that they only illustrate certain dimensions of an issue...So I don't think that's only true of maps, I think it's true of most evidence that it will not always give you all the dimensions that you possibly should be taking into consideration* (H, 3/126).

These questions, amongst others, are returned to and discussed in chapter 8. GIS was seen by some to have the power to construct reality by relating numbers, values and measures to real-life parameters.

> *I think a lot of councillors find it much easier to relate to stats if you can see how they relate to streets that they know on the ground. It makes it real for them* (U, 8/380).

By using maps to construct the reality of an issue, GIS was harnessed as a means of negotiating power to make 'deaf ears' listen:

> *I mean I very much used it as a presentation tool really. I suppose to try and explain further what the reality was 'cause I was getting the feeling that people weren't necessarily listening to what I was saying from the point of view of either showing information written down in sort of statistical terms or just verbalising. So it seemed to make a lot of sense to put it into some sort of graphical display as a map* (M, 4/182).

It is clear from the above response that value tagging was associated with data visualisation properties of GIS. Others, whilst acknowledging the use of GIS for presenting and communicating information, equated the value of GIS with its analytical power. These respondents tended to have more first hand experience with GIS and, without exception, were from medical backgrounds, which may account for their *analytical* approach to GIS. Several respondents in the study see the future of GIS and the power of GIS lying beyond simple data visualisation. One goes on to contest that there is no evidence to suggest that progress has been made in the past ten to fifteen years in extending the capacity of GIS in terms of analytical prowess. The development of GIS in

public health according to this practitioner appears to have reached a plateau. When asked whether GIS was used for visualisation purposes he replied:

> *Yes and that's not where the power of GIS is...Now in fact the thing which hits me when I think about GIS is that we haven't really moved on from there which is datasets that you can easily get access to that are spatially referenced and related to things like economic features* (L, 2/65).

Another participant argued that GIS applications, at present, tend to be descriptive rather than exploratory or explanatory. The NHS decision-maker explained that the use of GIS is *...very much to demonstrate rather than investigate* (W, 2/93). Many agreed that one of the most valuable functions of GIS is in enabling the integration of data. Indeed the mapping report, while illustrating some of the advantages and disadvantages of GIS, involved a data integration exercise (the overlay of multiple, disparate data to provide information on the issue of potential childhood lead exposure in Newcastle upon Tyne).

> *With GIS we're able to sort of overlay lots of different types of information on top of each other based on the locations of people you're interested in. So it's more flexible* (I, 5/208).

To summarise, participants talked about the use of GIS for visualisation purposes, to integrate various strands of data and (less frequently) as an analytical tool. Discussion now powers on to consider the power discourse.

7.5.3 The power of GIS in the public health domain

Many of the narratives drew attention to, or in some cases mentioned implicitly, the changing flux of the public health world, especially the NHS. Organisations are not in a state of equilibrium and neither too is the public health arena itself, where changing environments, the introduction of further targets and organisational restructuring lead to chaos, disorder and often resistance. Re-patterning, re-programming and adaptation are required to keep afloat in a constantly changing environment.

> *Sometimes in this job I feel as if I'm on the edge of everybody's priorities because everybody has their own set of targets to reach. And sometimes the targets for different organisations actually work against each other* (H, 9/423).

Despite being bombarded with new directives, initiatives and targets, participants were open to the idea of using new technologies like GIS mapping. Generally respondents valued GIS but many suggested that in some instances it might not be the most appropriate method for data analysis. Overall it was recognised, however, that the value of GIS in public health was related to the research or practice question to be addressed.

> *I think it has the potential to be a real tool, what we've always longed for in public health, a means of taking issues and turning them into something that is accessible so that people can take action, people feel empowered to take action. In order to do that they need to see why they should, to see why it's important. So yeah, adding GIS to our portfolio of ways of doing that is part of the future really* (P, 11/546).

From the above dialogue there is a sense that GIS is being thought of as a tool to garner political will in order to foster change. Other discussions yielded similar sentiments, that GIS was something to consider and not just a passing fad and though resources would be required to take GIS projects forward, ultimately this was would be a beneficial and positive investment.

Participants were asked to talk about their thoughts on the advantages and disadvantages of GIS technologies and what functions in the GIS toolbox they felt were most valuable. The responses received covered a range of issues but could broadly be related to how respondents perceived certain problems which was ultimately dependent on their experience, knowledge and belief system. In a rather crude way the status participants ascribed to GIS, the focus they put on certain functions and how they saw the potential of GIS was directly related to their epistemological position (how they see reality, how they visualise problems and how they devise solutions). In other words (GIS) status appears to be related to data origins (how the potential of GIS is framed by users).

Individuals who 'knew' GIS and had first hand analytical experience tended to rate it more favourably than those who did not. Indeed some decision-makers considered it a valid alternative to more traditional forms of epidemiological enquiry (see extract below). While others viewed GIS simply as a means of presenting information and communicating information:

> *I do think it's important and there are specific circumstances where GIS would be my first choice and I think an exposure or indeed a pattern of disease around a focal source would be one of those but there are others as well. So I think it has strengths but it also has shortcomings but so does traditional epidemiology and we use that without a second thought really* (I, 4/160).

The analytical power of GIS to demonstrate a disease gradient was described alongside the capacity of GIS to include a temporal dimension. The notions of time and place are discussed further in the proceeding chapter. There was a marked dichotomy between medical professionals and non-medical professionals on how participants approached the interview and the subject of GIS. NHS based practitioners tended to be protagonists of GIS and spatial forms of enquiry. This pro-GIS approach was hallmarked by voicing

issues regarding uptake of GIS, concerns about data quality and the dependence of GIS outputs on good data. Decision-makers in the community and environmental sectors seemed to be more realistic and pragmatic about the capacities of GIS. Of course these individual opinions and views would be determined by core belief systems, values, past experiences and tacit knowledge.

> *Well the main benefit of GIS is that it gives you a different way of analysing data – that's the main benefit. The sorts of techniques you'd use originally is case control studies, well the problem of case control studies is the control. More often controls are identified on the basis of their physical rather than spatial characteristics and for a lot of environmental issues in particular the spatial characteristics are more important* (L, 4/182).

> *With GIS you can accurately describe a person's disease status in relation to their distance from the source and the length of time they've been there. And there's no other tool you can do that with. You can include space and time* (L, 5/219).

> *The other thing is that we don't use GIS in a way that we could potentially to look out the strength of cause and effect* (L, 5/206).

This discourse focuses on the epidemiological power of GIS as an important benefit of GIS. By relating the value of GIS to the biomedical paradigm the respondent clearly articulates to himself and to the interviewer his world-view and value system.

In contrast, others frame the benefits of GIS with a completely opposing epistemological lens. They did not see GIS as a means to measure things or look for cause and effect relations. Instead, GIS was viewed as a useful means of communication that could cross boundaries and was accessible to all:

> *People remember pictures rather than…When we are talking about the wider community, certainly in Derwentside and County Durham and the North East, having very low levels of literacy and numeracy we need to present information in a way people can understand. Not being patronising but a lot of people don't understand percentages so the worst ten percent doesn't mean anything but if you show it on a map they can see how big that is or ninety per cent or whatever. So I suppose it simplifies statistical terminology* (J, 6/254).

An anomaly to the observed dichotomy, whereby NHS based practitioners view GIS as an analytical tool and non-medics see GIS more as an aid to communication, is evidenced in the following remark made by a senior decision-maker based in a PCT:

> *It's self-explanatory and individuals themselves, a good proportion of the population see the world or interpret the world in a visual way. So for those people, maps are excellent and even for the people who are the kind of feeling people out there who experience in a feeling way they can actually get a grip, touch maps and relate to them themselves as well. So it's a relational thing for them as individuals in a way that they can't see themselves in a table they can*

certainly see where they live or where somebody they might have never met or seen lives (W, 9/449).

The respondent (a female decision-maker working in the NHS) suggested that GIS maps represented a democratic means of communicating with people who come to know or understand the world in different ways (see/hear/feel). Perhaps the value practitioners attach to GIS is more an issue of gender. In this way GIS as an analytical tool would fit into the patriarchal world of positivism. Conversely females might support less reductionist and quantitative ways of knowing (Oakley, 1998) and therefore might afford to GIS a multiplicity of benefits. Oakley (1998, p.707) discusses the three Ps: positivism, power and p values as tools of obfuscation when she assesses the feminist case against "malestream" methods in social research.

Some individuals were able to recognise both the analytical benefits of GIS as well as the power of GIS as a democratic communication tool:

> *Well it appears to me to be a great way of juggling, for want of a better word, lots of different datasets and making sense, painting a picture, a bit like epidemiology where you actually create patterns out of data. And the patterns can lead onto new, meaningful interpretations and conclusions. Yes and the only other techniques that are able to do that are very complex statistical things, which aren't very accessible to many people certainly not. So it's much easier and accessible to more people* (W, 6/254).

Others, still, were rather ambivalent, neither arguing for or against a particular function of GIS. 'Fitness for purpose' was emphasised when determining whether or not to employ GIS in a certain situation.

> *It all depends on the audience and I think it depends on what you're trying to do. The benefits will be the same for me, it's all down to intelligent use of maps in the way that you want intelligent use of graphs, tables, pie charts, any other way of showing data or information. So it can be helpful if it is able to convey a point fairly strongly. I think it can be very helpful in providing a sense of perspective.... I think it's helpful if you set it, a map may be able to do that, provided that you can take away a lot of extraneous data to make the information so it's quite clear what's going on. I don't think, in a sense, there's a particular thing about maps that make them any better than the other approaches. I think it's very much horses for courses* (S, 4/154).

Several participants questioned whether or not GIS was appropriate for all situations especially when a result could be ascertained using a more straightforward and less time consuming method.

> *Maps are an extremely valuable way of presenting data but actually for the sorts of things we want to know, like for example is there any difference between the blood lead levels of people who lived around works in Benwell. It isn't Benwell it's next door to Benwell, within 600 metres of the works and is one kilometre any different? You don't actually need a map to know that but if you wanted to present it to ...that would be useful* (L, 4/172).

> *All of the datasets that are developing in terms of health are things like hospital activity data, off the top of my head I can't think of a good reason why we'd ever want to use GIS for that" (W, 8/374). I mean we look at rates of usage in terms of whether there is an inequality, some people get more exposure to certain operations than others. But, that's easier statistically for me* (W, 8/380).

In contrast, Kaukinen and Fulcher (2006) employed GIS technologies to address such questions around how service provision relates to service need. Using the example of HIV services in Canada, Kaukinen and Fulcher mapped the distribution and accessibility of HIV services across Toronto and overlaid spatial data relating to social demographics. Tellingly, the patterning of service provision was not homogenous and there were explicit pockets of unmet need. Many disadvantaged communities were underserved by accessible HIV and AIDS services with immigrant, minority and economically disadvantaged communities being disproportionately affected. The authors suggest that policy makers should employ GIS techniques to determine the optimal locations for new services, which take into account factors such as race, migration, socio-economic status and health need (Kaukinen and Fulcher, 2006).

A number of interviewees suggested that in some circumstances the use of GIS was superfluous especially if the spatial geography was well known and understood:

> *I mean when you know an area for me having that information in maps won't particularly add anything different than the data I've already got. So I'll get the value out of looking at the causal stuff but it will provide an alternative way to present it to people who don't want to know about the facts and the numbers* (J, 13/621).

> *Such things are done automatically using what's up here* [gesturing towards head] *rather than looking on a map, because people invariably know their area.* (F, 11/530).

Conversely, a senior decision-maker in a NHS related organisation drew attention to the power of GIS to incorporate temporality into mapping displays. Thus GIS applications have the potential, not only, to demonstrate issues of space and place but also to include temporal perspectives.

> *With GIS you can accurately describe a person's disease status in relation to their distance from the source and the length of time they've been there. And there's no other tool you can do that with. You can include space and time* (L, 5/219).

In practice, GIS can be used to demonstrate changes over time. For example a study by Krause, Frate and May (2005) used a time series GIS to show changes in the distribution of dentists across time and place. Equally, GIS techniques can be employed to illustrate how a particular phenomenon can

remain constant over time. Dorling and associates (2000) study of the embeddedness of health inequalities, in central London between the 19th and 20th Centuries, exemplifies such an application.

There was a recognition that it was not only decision-makers who needed to understand the value and usability of GIS, practitioners working on the ground in public health should also be able to grasp the central precepts of GIS science. One respondent speculated that GIS would not be the obvious choice as a tool for analysis because it was still seen as something removed from day to day public health practice. In this way it could be viewed as a technocratic tool or device. GIS is not available to all public health practitioners and does require a basic understanding of mapping concepts and a familiarity with GIS language and potential mapping applications.

> *There's a bigger issue there and that's the perception of public health people of GIS. It's seen as something a little bit esoteric still and technically difficult and it's in the same bracket as mathematical modelling of risk you know which can be used to do similar things. So I think most Public Health Directors when thinking about the analysis of a problem would not automatically think of GIS as one of the options available to them* (I, 333/133).

The same respondent went on to suggest that if GIS had emerged in public health rather than geography, understanding and consequently uptake would be much greater than in the present situation.

7.5.4 Limitations to the power of data

When prompted about the shortcomings of GIS data a number of issues, mostly of a practical nature, were reported. Eight limitations or shortcomings were cited by respondents as set out below (in order of frequency):

- Data quality/quantity (also evidenced in section 6.5.1);
- Lack of resources: software/hardware; trained staff; infrastructure to sustain use;
- Data availability/accessibility;
- Data confidentiality/sensitivity;
- Disparity in boundaries;
- Technocracy (as evidenced in section 6.5.2);
- Licensing issues;
- Differences between packages.

As well as talking about data quality issues and maintaining a stable infrastructure to implement GIS, one respondent emphasised the need for organisational will and commitment to guarantee the success of GIS.

> *I think the major limitations are the data quality but also the infrastructures for actually achieving data capture and at the moment we're in the sort of flux of waiting for the national programme of information within the NHS. We haven't really progressed very well in recent times to be able to overcome some of the difficulties in capturing information. So I think if only we were to move on and progress with that, then it would be much better and I think where there's a commitment really as well for us to be able to get the data that we need...So it is very much about the infrastructures...and the commitment really to making sure it's in place* (M, 5/216).

More than half of the cohort interviewed agreed that limiting factors existed in relation to resources and specifically a dearth of technical expertise, which is obviously costly.

> *We're in the position that we have at least three people who are reasonably advanced GIS practitioners. I don't think any of them use their skills regularly if at all. So we almost never use GIS as far as I'm aware. The sorts of things that GIS are used for are largely producing very simple maps, which actually you could do with a drawing package* (L, 4/159).

> *The main limitation is inaccessibility. You need technical expertise to use it and you need that to be available at a reasonable cost and until it becomes much more generalised and much more mainstream then it's always going to be expensive and difficult to acquire* (I, 5/224).

Clearly there is a disparity here in terms of organisational resources: one agency has skilled GIS practitioners whereas the other has the will to use GIS but lacks the practical expertise required to implement GIS techniques. This seems to present an ideal opportunity for collaboration and sharing of skills and knowledge within the public health domain. Another participant worried about the cost of GIS and volunteered that despite procuring the necessary equipment, GIS was rarely, if ever, used because nobody had been given the appropriate training.

> *I know some of the GIS technology speeds it up but often that is quite resource intensive and often that work is farmed out to consultants so often there's a cost to it, there's a time cost and an actual cost that people don't like to incur....I don't think it's used that often...my impression is that it's not in everyday use...they're not running it* (H, 7/306)

A number of respondents were mindful of the issues around confidentiality, disclosure and sensitivity:

> *Yes identifying people so something useful might be around sudden infant death syndrome where there's an environmental thing around power stations but that's such small numbers and they don't want to postcode that...It's alright when it's huge numbers, it's routine data but yeah. I suppose if there's a public good out of it, like an environmental hazard then that makes it more acceptable* (W, 7/312).

> *There are lots of rules around disclosure control, very confusing rules and it depends upon which organisation you're dealing with they have different rules about that and it's in a sense finding ways round some of those rules and presenting data which are useful* (D, 2/92).

Ethical issues in relation to mapping and the display of sensitive or confidential data in GIS packages have not been debated in depth and few organisations mention the use of spatial data specifically in their ethical codes. Interestingly a decision-maker from a NHS related agency was keen to consider issues around governance and ethics in the use of GIS maps as evidence as part of the organisational ethics code.

Issues of a practical nature such as licensing and differences between GIS packages were also thought to be constraints against GIS uptake. GIS licenses, as well as the packages themselves are prohibitively expensive for small organisations where budgets are tight.

> *We also need to be aware of licensing issues as data often has intellectual property rights associated with it* (C, 2/61).

> *We scratch our heads and say yes IT is a wonderful thing but people are, I don't know, putting barriers in our way of using it to its fullest potential. I mean the costs of purchasing these systems and using these systems year in, year out, it can be significant, particularly when you, you know you're looking to make savings and cuts and you've got this ongoing cost (for licensing)* (F, 13/609).

When asked about GIS uptake a decision-maker from a local strategic partnership (LSP) explained that the LSP contracted out research that required specialist packages as their resources were restricted in terms of skills and training.

As with almost all public health issues it is difficult to avoid the influence of politics and the range of political drivers influencing evidence-based decision-making not least issues of confidentiality and disclosure. One participant, however, believed that although important, confidentiality rules should be approached with a common sense attitude. His focus was on protecting the population ahead of protecting individuals:

> *So for example the data extracts that you can get from General Practice now are potentially better if you can get round all of the...data protection and Cauldicott rules but we don't do it routinely because it's hard...And one has to ask yourself is absolute privacy for things which are often not very sensitive important if balanced against minimising risk to those people...At the moment we have sort of the EU purity vision that personal privacy is absolutely paramount. I'm not sure that personal privacy is as paramount for the things that we're often interested in* (L, 4/123).

A number of participants with hands on experience of GIS were concerned about the multiplicity of boundaries in existence, leading to problems of comparing like with like.

> *I think one of the problems, we talked about a technical point one of the things is we tend to be constrained by administrative or population boundaries and there's always a problem if you start mapping other variables into those boundaries* (N, 13/600).

Others pointed out the limitations of administrative boundaries, which are static and artificial. By imposing these sterile boundaries data analysis could be flawed leading to artefacts in the findings. These problems are augmented because political boundaries are subject to deconstruction and reconfigurations:

> *I do think that people aren't able to do the multi-layered stuff so they just do two "axes"....And so really you're restricted to things that are geographical. Then the artificial boundaries, the way that you carve up your map and traditionally we do it by wards. But when you're looking at environmental things in fact they're completely meaningless aren't they? So actually it would be better to have hills or dales or rivers or whatever, something relevant...communities, housing estates would be better.* (W, 9/479).

Several respondents worried about public health practitioners grasping the technical nature of GIS applications, which necessitates understanding of mapping concepts, familiarity with geographic terminology and a 'computer friendly' disposition. Some interviewees actually believed that there was a fear of GIS within their organisation. These feelings of anxiety and fear may limit uptake and use of GIS map outputs as well as the technology itself.

> *There is a fear of GIS technology but really it's just another software system. It does require some skills that can be provided with the relevant training* (C, 2/48).

> *And the other side of the coin is nor would there be sufficient people around a table with the skills to actually understand what's been done. It's almost too sophisticated for the state of the current National Health. That's my concern. Now a straightforward map that I've talked about that's not but GIS is too sophisticated* (W, 3/142).

> *The sophistication of it: it's quite technical, it's very numerate and a lot of people in health aren't that numerate* (W, 4/150).

> *There's also the issue of selling it to people not just those who might want to use it but to the community who might want to act on the results, who understand epidemiology but don't understand GIS* (I, 5/227).

The latter excerpt is one of only a few quotes that make reference to acting on the results of a GIS exercise and making use of map outputs in practice. This calls into question whether or not public health practitioners 'see' GIS as a pragmatic tool that can be employed, realistically, in the decision-making process. Finally, one participant was concerned about the diversity of

GIS packages and the associated compatibility issues that he felt could impact on sharing data and information across the health sector

> *There's something about the difference in the way GIS is done in different places. Different units become familiar with different packages and if one unit is using MapInfo and one place is using something else then you do get different outputs, different views, different pictures. Whereas if you look at epidemiological outputs they all produce similar things in that they all use the same kind of bar charts, histograms and things* (I, 6/260).

An issue to consider here is the relative age of the different technologies. SPSS is was introduced before MapInfo® and ArcGIS® and perhaps as GIS packages develop there will be some consensus on standard graphical outputs.

7.5.5 Maps as evidence

Respondents talked about different types of evidence (including experience, tacit knowledge and expert opinion as well as quantitative and qualitative data) that could be drawn upon in decision-making processes. When asked to comment on maps in public health practice, participants were quick to recognise the potential but at the same time were sympathetic to the nuances involved in map making. There seemed to be a feeling that maps were rational and reasoned sources of evidence to underpin decision-making pathways.

> *I think it's such a good way of illustrating points 'cause a lot of these issues get to be very emotive and all sorts of things come into them so I think to be able to have a map it's just a good piece of evidence that you can put in to try and make the decisions more rational* (H, 3/102).

All twenty-three decision-makers interviewed believed that maps were a valid means of presenting data that is not to say, however, that they were blind to the caveats associated with maps as evidence. Significantly, a number of participants pointed out that a key benefit of maps is that people can relate to them, they are familiar and for that reason non-threatening.

> *I think that culturally we are, as a society, used to maps...We see a weather map every night on the TV.* (W, 6/282).

Similarly, maps were thought of as user-friendly and accessible and for this reason they could engage an audience and facilitate understanding of complicated or contentious issues.

> *And so that maybe for those who are frontline workers perhaps, it's quite important for them to have an understanding about what it is that they're trying to achieve in way of supporting the targets, maybe that's something that can be used much more readily and it's much more user-friendly really to be able to convey the right messages really, the right information* (M, 7/320).

Many respondents compared maps to statistics as a means of presenting data. Maps were felt to be more accessible and easier to understand than statistical tests, graphs or tables, which might disengage some members of the public health community.

> *I think the other thing is that where people aren't particularly hot on statistics and analysing statistics that it is so much quicker for them to be able to look at and identify where the colours are coded or whatever. So that I mean obviously it's still useful to still have the statistics in terms of benefit. It just helps perhaps for those who are not quite so ofay with using statistics* (M, 7/312).

> *Anybody, well not necessarily anybody, can read a map. I've found that it can be tricky but there is a perception that maps. We've grown up with maps. They're childhood things. Jigsaws are childhood things. Traditionally it's not a challenging or threatening skill. Something like a statistics correlation co-efficient is immediately a turn off* (W, 6/270).

> *I do think that's really, really useful because of all sorts of things. Like I was saying before, culturally maps are acceptable so people are used to dealing with maps. Maps are interesting because they're usually colourful and they're different shapes so they hold people's attentions. Again it's away from the graph thing, which is very much about school and numbers that turns people off* (W, 9/426).

More specifically maps were thought to be an effective way of demonstrating variation across an area:

> *I suppose showing geographical variation in a very obvious way, very quickly with one slide you can show geographical variation across the whole country* (I, 7/344).

Several interviewees viewed the process of map interpretation as, essentially, a subjective exercise:

> *People's perceptions will always influence what people see on a map. Sometimes people only see what they want to see. I haven't specifically had anyone say I don't understand that but people look at pictures in different ways don't they?...And maybe we need to, I suppose, explain more about what it means to create that joint understanding to see the same picture if you see what I mean* (J, 8/352).

Participants were invited to discuss what they believed were the central disadvantages or handicaps of maps as evidence. A number of themes were recurrent, especially the way in which maps can over-simplify complex issues.

> *Well it does appear to over-simplify things (*W, 10/472)

Rather than effectively handling the complexity of an issue, there was a suggestion that GIS and the use of map representations might in fact oversimplify issues. This finding conflicts with the proposition that GIS has the power to manage complexity through the overlay of multiple disparate datasets in an attempt to uncover subtle patterns and inter-relationships.

The analytical power of GIS was felt to be compromised by its inability to calculate simple statistics. To qualify that a relationship is more than just chance, spatial statistical modelling is required such as krigging (refer to glossary, page 269) and to even the most statistically literate public health decision-maker this is a totally new undertaking.

> *It's hard to show confidence intervals on maps* (W, 9/472).

In other cases, conclusions can be drawn on the basis of too few data, for example on one year of data. If small numbers are involved it can be erroneous to calculate rates which show large changes; for example, zero peri-natal deaths rising to one in the following year, is a one hundred per cent change but when the numbers are drilled into the rate changes are meaningless (example volunteered by participant based at Agency D). Of course the same criticism could be levelled at data represented as statistics: a fifty per cent increase in a parameter could equate to an increase from two to four cases.

> *I think you have to speak to people and explain what you're trying to achieve through that. So you can't just show them, necessarily, depending on what the subject matter is really without having some background to it and some understanding* (M, 9/412).

The respondent quoted above, cautioned that maps need to be presented with some dialogue about where the data come from and what they are attempting to present (metadata). As with any type of analytical data presentation, the maps should be contextualised to give the audience a full understanding.

7.5.6 Maps, misunderstanding and misuse

During the first interviews conducted, it emerged that maps as well as having the power to facilitate understanding, equally have the capacity to promote misunderstanding. Early in the series of interviews two participants remarked that a major disadvantage of GIS representations is their inherent capacity to mislead or be misunderstood:

> *The disadvantages are I think you can, it's perhaps open to more, not necessarily interpretation, but it's easier to probably mislead* (N, 12/591).

> *To some extent I suppose there is a responsibility to GIS to make sure that the right message is coming out. If you follow the line that a lot of people find it easier to understand something when it's presented to them in that form it's also easier for them to misunderstand it* (D, 11/543).

The latter excerpt cautions that there is a responsibility to deliver the 'right' message using GIS data. Whether the interviewee is referring to 'right' in the sense of 'judicious' or 'right' in a moral or political sense, is open to debate. Similarly, Monmonier (1997) cautions that there is much potential for maps to be politicised and used as propaganda or vote wining devices.

To return to the issue of misunderstanding data, a participant involved in data management and analysis volunteered an example where data were misunderstood. Stretch targets[13] were determined locally for smoking cessation but the wrong variable was used to measure change: of the number of people given a quit date they would increase the number who quit at four weeks. They could, however, achieve this target by decreasing the number of people to whom they gave a quit date, so in effect they could attain the stretch target by doing less work. A more useful measure to employ would be proportions of the population that is the proportion of people who quit at four weeks of the population as a whole.

> *Because people don't necessarily understand the ins and outs of health data they've come up with that as a target in all good faith, but to me it's a nonsense....It's, in a sense, a perverse target.* (D, 3/141).

Clearly, the importance of understanding the scenario, the salient factors, the actors, drivers and constraints was demonstrated to be as important as understanding the data themselves. This example did not involve the use of GIS so it seems that any form of data representation is subject to misuse, partial views or misrepresentation. This theme was picked up and explored in the later interviews when participants were asked to talk about times when they felt GIS maps had been (i) misunderstood or misinterpreted; (ii) used erroneously and (iii) received negatively. One respondent even picked up on the theme of misuse of GIS before being questioned about it:

> *Because obviously as such you're democratising the access to this kind of stuff and there's a danger that actually people will misuse it* (U, 5/209).

Many participants related to these problematic issues and recalled instances where this may have occurred but were unable to think of specific examples. One example of misuse and misunderstandings is illustrated in the following citation. The key point is that the data producer and data interpreter different people with different understandings of the issue:

[13] Means of augmenting PSA targets by implementing additional resources in a localised setting to achieve greater positive change.

> *I have a limited amount of experience. I think this project I originally said about the University and these cases of primary biliary sclerosis and we were trying to map the clusters and relate it to water supply. But my concern all along was that we didn't know they were true clusters. I didn't know whether there was a complete dataset and whether it was about case identification...Again it's back to...I suppose when I was at the university there was a lot of interest in GIS but it's back to that business where the person who does the GIS doesn't necessarily understand the dataset given to them. So they could do really fancy stuff but I never really sensed that they fully understood the dataset or the person that gave them the dataset fully understood* (W, 14/652).

These comments echo the thoughts of another participant who emphasised the role of probity and the integrity of the individual responsible for communicating data about complex issues in an honest and trustworthy manner. This particular individual volunteered that the mapmaker has a responsibility to the audience to produce data that were easily and intuitively interpretable.

> *I think also there's a kind of assumption that because you've done something other people will understand it* (D, 12/576).

> *So there is a need to be quite clear about it and the best way to be clear about it is to try and do it in a way that most people would understand intuitively. There's a whole set of learning there that you could go through to try and enhance the use of GIS in that way* (D, 12/593).

There are clear links between these narratives and the construct of data sharing and reciprocity, which is discussed in detail in section 7.7. Respondents understood that practitioners need to work in collaboration to bring together complementary areas of skills and expertise, to share knowledge and to foster joined up working. Drawing on a significant feature of complex systems thinking: the whole is greater than the sum of its parts, the capacity, effectiveness and efficiency of a multi-disciplinary team is likely to be far greater than the component parts (individuals or organisations) working alone.

Several interviewees speculated that problems related to misunderstanding data were propagated when there was a gap between the map producer and map interpreter.

> *Yes there was a gap in terms of the partnership between the GIS expert and the dataset expert. That's a really interesting point because yes you can produce these very pretty maps but whether they actually mean anything. Yes and the map producer will never know at all and will actually be very proud of what they've done and think it's fantastic* (W, 14/661).

> *There was obviously a mismatch between the people that created the data and those who were involved in communication* (D, 4/190).

When questioned about how audiences have received GIS maps one respondent contended that the experience had generally been positive and any

doubts had been borne out of people's unfamiliarity with GIS techniques and concepts.

> *I think if anything it has been more positively received. I think it's perhaps if anything, it's perhaps people's lack of using them that maybe makes people question, particularly if they've never seen maps in use for very much clearly indicating what the data's showing* (M, 9/432).

Conversely others described situations where GIS map evidence had been doubted most notably in the case of a sensitive and contentious causality relationship:

> *I think any situation that is highly politically charged like the leukaemia clusters and power stations for example some people because of the sensitivities don't accept the evidence or doubt its power because it isn't demonstrating what they want it to show* (W, 16/774).

Complexity theory provides a framework to make sense of phenomenon with both ordered and straightforward components but also disordered, messy or problematic dimensions. From a theoretical perspective to abandon the issue simply because it raises contentious issues would be to ignore the fundamentals of complexity thinking. In other words, because GIS representations may draw together data that raise eyebrows or evoke a hostile or defensive response is no reason not to undertake the GIS mapping exercise. In this case an overlay of leukaemia clusters around power stations might not provide robust evidence about causality but the map does provoke interesting questions to invite further debate, which might also stimulate the design of explanatory studies.

7.5.7 Discussion of power debates

There was widespread recognition of the need for a robust evidence base to underpin decision-making at a local level. Overall GIS technologies were seen as positive and constructive tools in public health decision-making. Often the decision to use GIS was a trade-off as to whether the map outputs were worth the efforts required to produce a spatial analysis. The quality of data for use in GIS was established as a primary driver of good practice. Accordingly, the absence of good (timely, complete, consistent, reliable, and valid) data significantly undermines the usefulness of GIS output representations in practice.

GIS was depicted as a useful exploratory tool particularly in the early stages of an investigation. Advantages of the GIS approach identified through

interview discussions were both specific and general. To illustrate, from a generic perspective the overlay operation was acknowledged to be an important and useful function in the GIS toolbox. More specifically, the flexibility GIS provides with respect to unit of analysis (spatial aggregation) was seen as advantageous and a means to circumvent the modifiable areal unit problem.

There was a concern about the use of GIS in a superficial way to produce what were often referred to as 'pretty pictures' lacking in any substance or meaning. A number of participants felt that GIS can construct reality in a meaningful way but a larger majority of those interviewed were more concerned about the potential of GIS to distort or falsify reality leading to misrepresentations, erroneous conclusions and ultimately the misuse of GIS data representations. A number of contributors valued GIS as a means of making complex issues appear more approachable and therefore manageable.

7.6 Functionality discourses (data application)

The theme of data application was present in the original theoretical framework, which evolved from the map-making exercise. Initial analysis echoed concerns about the application of GIS principles and the use of the technologies in day-to-day practice. Questions were posed as to whether GIS was working and whether it could truly offer something beneficial to the public health arena. From these discussions there emerged a feeling that GIS could be valuable in decision-making and potential opportunities for application of GIS methods in problem solving were highlighted.

7.6.1 Use of GIS in evidence-based decision-making

Respondents tended to adopt a pragmatic perspective where if GIS did not work in a particular instance they drew on existing traditional techniques. For example:

> *It only provides you with information about geographical information. GIS is not an analytical tool* (A, 7/313).

One participant was particularly keen to highlight the role of GIS in decision-making. Without probing she emphasised the need for robust and coherent evidence to underpin decisions.

> *The other point I guess I would like to make, to go back to the decision–making thing, is that Directors of Public Health have to make difficult decisions in a climate of sometimes not enough information…They also have to advocate for*

> *people's health. And the clearer the information is and the more powerful, the more powerfully it is presented then the easier their job is* (Q, 12/572).

This remark resonated with a response gathered during the pilot interview:

> *I think it can be very useful and valuable as a source of evidence. Just using it as a visual aid is particularly important because you can present data in such a way that you wouldn't be able to see from maybe tables or charts. I think it is important and a valuable source of evidence to be used in decision-making processes, definitely* (Pilot, 3/125).

The use of GIS to summarise data quickly and efficiently for strategic decision-makers was also highlighted:

> *I think huge lumps of text, you don't want to be sat there reading…. for top level people who don't want to know the nitty gritty, they just want to look at some graphs or some maps, an overview. That's where it would come in better* (O, 2/99)

Despite the efficacy of GIS to summarise data, decision-makers were aware of the potential for GIS maps to be manipulated to influence how data are displayed and consequently the message communicated though spatial representation.

When asked about the functions of GIS, one respondent cited the use of GIS in supporting or making a case for one particular course of action. The 'visuality' of GIS map representations lends itself to this particular application. As already discussed, maps tend to appeal to a wider audience than numerical data displays and are accessible in ways that other representations are not. Their role in advocating for a particular action or decision to be taken may be directly related to their power as 'immediate', 'visual' messages.

> *Unlike statistical data, GIS maps are a nicer visual tool. And there's potential for GIS to play a supporting role in presenting an argument* (C, 1/42).

A number of participants were mindful of the limited availability of data when engaging in decision-making processes. Interviewees tended to be practical and realistic about these constraints:

> *Yes it's the art of the possible. You use what you can. If there's some data there that you can do something with, they might not be quite as good as you'd like them to be but it's better than not having it* (G, 7/297).

7.6.2 Uptake of GIS

There seemed to be agreement that uptake of GIS was still less than optimal

> *I think it's hardly ever used at all. I don't think it's necessarily seen. I don't think people really see it as useful* (M, 4/150).

I would say at the coalface, it's underused and it's probably of limited value to be honest and that's very much a modern day phenomenon. I've been in public health since 1990 and up until 97 things were getting quite sophisticated and we were probably getting into a position where a GIS would be very valuable but the reorganisation diluted all of the management and expertise within PCTs so you end up with a work force which really weren't experienced in anything technical and very much under day to day pressures so it has very limited value. In using a computer technology there isn't enough money around to pay somebody who would be skilled enough to do that job properly (W, 3/129).

When asked if it would it be fair to say that GIS has little status in the PCT the decision-maker replied:

Unfortunately, I think that's a shame and I think it's just a symptom of the way management and health service management is at the moment. Health services research that's fairly under developed too (W, 4/163).

Others suggested that there had been a stasis in GIS developments in the health sector in the past ten years.

Now in fact the thing which hits me when I think about GIS is that we haven't really moved on from there which is datasets that you can easily get access to that are spatially referenced and related to things like economic features (L, 2/65).

I think that's why we don't use GIS. It's because it's a sophisticated technique, which requires better data than we have. And the only way you can afford to do it, and afford in the broadest sense is effectively for a special study. So when you've got a problem that you can't resolve any other way, you use GIS. One of the things I don't know, I think nobody's ever proved this is if you can use GIS for more routine problems with any great benefit. There's lots of techniques you tend to use for looking at potential clusters of say communicable disease rely on more routine data and things like local authority residence. That may be enough actually because if your local Chinese takeaway is feeding you salmonella then it may well be that it would be more relevant. Actually being able to demonstrate a cluster in the streets down around the takeaway, which you could probably do in those circumstances is icing on the cake (L, 2/89).

The use of GIS in outbreak management presents a forward-thinking opportunity for mapping applications. In infectious disease epidemiology, place makes up the familiar epidemiological triangle model with time and host, which drives outbreak investigations. Implementation of such techniques given the appropriate resources and expertise within a supportive environment could supplement more traditional approaches to outbreak management in and beyond local authorities.

It was suggested that if GIS were used more often, then data sharing could be augmented.

I think if it were more widely used by the key organisations, which provide information to a lot of organisations. We don't see it very much, for example, in Public Health Observatory Reports, even in government reports. We don't see it in the Chief Medical Officer's Report or anything like that so there are other opportunities to promote its use or demonstrate its value I suppose which we don't seem to be taking. And as long as we keep churning out the same kind of

models it's going to reinforce the use of epidemiology as the only tool, which is unfortunate (I, 7/308).

One respondent looked outside of her own organisation and observed that in others the use of GIS was far more common place

In some local authorities I think there's a lot more development around the technical side than others. I think in general there is a lot more money around and they're very attracted to the idea of having all of that technology. I think they find it very attractive but I would still challenge whether they would be using it effectively that would be my perception at a grass roots level, of local authority environmental health officers (W, 5/207).

When asked how often GIS outputs are present in health reports the response was seldom and at best once a month:

Probably once a month. It depends what I'm doing...hmm, what way? A descriptive way, yes usually to show [pause] currently it would be around inequalities. So different smoking rates, different obesity rates or even different hospital admission rates. For analysis, I don't think I've ever seen one [laughing] (W, 11/557)

7.6.3 The potential of GIS – possible applications

Participants saw a multiplicity of potential uses for GIS in, around and beyond the public health agenda. The first excerpt considers the capacity of GIS to make sense of temporality. The second draws attention to the power of GIS to explore the multiple inter-related social, environmental, political and economic aspects of public health issues and to unpick how factors are contingent upon one another.

It would be useful to both look at statistics but also the maps on a year to year basis and make some comparisons to see whether we are making change or making improvements. They're not used really (M, 4/175).

You could do kind of things like childhood obesity and proximity to certain shops....all of that healthy eating, the food co-ops all of that...And there is something around and we don't do it very well and we haven't yet so maybe GIS is the answer about stacking up the whole thing around wealth in terms of education and income...Like a composite because what we don't know, we know that all of those things influence health but what we don't know is which is most important. And GIS you could probably help come up with that answer (W, 13/617).

There was a recognition that the capacity of GIS to integrate multiple and varied indicators relating to health was well suited to address multifaceted public health problems. This overarching ethos is in keeping with the key notions of emergence and contingency central to the complexity programme.

Whilst acknowledging the current use of GIS as a tool for visualisation a number of respondents were keen to voice their thoughts about the potential of GIS beyond basic cartography:

GIS is used here as a visual tool for spatially referenced data. We use GIS to combine datasets to produce visual pictures. We would like to advance the use of GIS as there is a lot of untapped potential there. It could be used as a decision-making tool and not just for display purposes (C, 1/32).

7.6.4 Discussion of functionality debates

GIS was viewed by many as an important tool to public health practitioners who act as 'advocates for people's health'. Evidence produced using GIS was perceived to be both useful and valuable. The capacity of GIS to quickly and efficiently summarise data to provide an overview of a particular issue was highlighted as important. The 'visuality' and immediate impact of maps makes them more accessible to a wider audience. While uptake of GIS was still limited, respondents looked to other organisations where GIS had been employed with success. It was felt that in some areas there had been a stasis in GIS development and use in health over the past few years. Data availability was seen as a limiting factor for application of GIS methods in practice and the use of maps as evidence in decision-making pathways.

Some practitioners viewed maps as neutral while others accepted the power of maps to advocate for a particular cause or decision. Finally a number of participants highlighted the potential of GIS beyond basic cartography, suggesting that there was, indeed, a role for GIS maps as evidence in decision-making processes. From a complexity stance, GIS has the capacity to illuminate inter-relationships between seemingly disparate datasets, which can potentially be used to assist and inform decision-makers operating in conditions of change and uncertainty.

7.7 Collaboration discourses (data reciprocity)

7.7.1 Collaboration and data sharing

The value of sharing data was clearly articulated, with one participant suggesting that combining and integrating different data sources can help to focus and clarify an issue:

On it's own the information that we have might not prove that point but putting it together, multi-layering it you've got sort of the information that you need and the answer in short is I think yes it's a good idea (E, 15/724).

Others, mainly those in the health domain, maintained that certain problems cannot be fully understood by looking at one data set in isolation, further data are needed to contextualise the debate. All participants talked about the

importance of partnerships and multi-disciplinary working and many examples of collaboration in action were received.

> With most projects you can't isolate one issue and look at just one aspect of a problem. GIS can provide an opportunity to work together in partnership to look at the problem in detail (C, 2/59).
> *So in a sense it was a tool to be used to support them in taking forward joint pieces of work that could be undertaken where it benefited to have a cross partnership approach to making a difference really in the sense of providing services. I think that's probably quite motivating in a way because people can see it so visually and hopefully it helps people to think well we need to concentrate on this particular area in this patch but maybe not consider something else within the patch because it's not such a high priority. And it allows people to think of things in more bite-sized chunks in a sense so that you're not really trying to work to such a huge agenda and they can prioritise certain things depending on what part of the city or whatever* (M, 10/485).

In relation to sharing data specifically, a non-health decision-maker talked about the barriers towards collaboration and the way in which he attempted to circumvent those hurdles:

> *So I'm part of the NERIP partnership which brings together 40 different partner organisations with an interest in information, exchange of information and one of the things that NERIP is actually looking at is whether they can start using information technology particularly GIS in a more intelligent way* (D, 2/54)
>
> *So it's quite, it's a fairly interesting development but there's an awful lot of, as you can imagine barriers between the sharing of information between partners* (D, 2/74).
>
> *A key part of my job really is finding ways round some of those barriers and sharing that bit of information that I can in a certain way whether that is anonymised or whatever. So that people can actually get access to data that they wouldn't otherwise have* (D, 2/80).

It became apparent that certain decision-makers, whose work already embodied an element of collaboration, were aware of the barriers to information sharing (see figure 7.3) and partnership working but were ready to engage in processes to overcome these problems.

To the question of whether there is scope to use GIS as a vehicle for sharing data to promote interagency working one participant responded:

> *Oh absolutely, but it's going to require people to be less precious about who owns the data and people to understand that the Data Protection Act doesn't necessarily mean what they think it means" (U, 13/632)*
>
> *I think there's a bit of a culture change needed there. It's about people, their first thought being yes we can share data and not let's find reasons why we can't* (U, 13/642).

There was a feeling that data were available but the linkages to ensure proper sharing and appropriate dissemination were not in place.

> *I think what was evident when working on this, and it's probably moved on since I was involved, was that there was so much information around but it wasn't*

> *being shared properly and it would have been a quite useful tool to use for that* (M, 12/551).

As the following extract demonstrates, the complexity of partnerships was generally well understood and articulated using the language and terms found in complexity discourse:

> *Because our partnerships are very complex, because we have partners in the voluntary sector, we have private sector representatives, we have public sector representatives and what we want, a good partnership is being able to achieve a common dialogue between those three people. It's not rocket science. I suppose the practice is much harder than the theory because they are all driven by a different ethos and it's trying then to find those common things to actually drive them all* (J, 8/392).

Notably the respondent quoted above represented a community partnership and saw GIS as a joint endeavour and a means of engaging with the community in contrast to other stakeholders (principally those with a NHS orientation) who referred to GIS in a less inclusive manner. The type of language used by the LSP decision-maker was open and accessible. Moreover, she adopted a collective and participatory tone when contrasted with other decision-makers who seemed less comfortable with the use of GIS for collaboration purposes.

Confidentiality and sensitivity were regularly referred to as barriers toward data sharing:

> *I think inevitably there's always the data protection and Cauldicott issues really that there are certain restrictions with regard to sharing identifiable data. I think what we're talking about predominantly is non-identifiable data. I think it's perhaps when it becomes very small amounts of data and I'm thinking the sorts of areas particularly might be… more sensitive or there might not be very many numbers in an area.and particularly if you're using postcodes and things you could perhaps expose an individual, not intending to* (M, 12/560).

> *I think the biggest barrier to us sharing data is the question of maintaining confidentiality…. I think is becoming even more important now and is certainly taking a higher profile* (D, 2/92).

Of course identifiability is a concern associated with all types of data display – not only with maps. When asked more specifically about barriers and territoriality many participants voiced their opinions:

> *Working in collaboration is very hard. Where do I start with the barriers? It is just very hard because of the different cultures, different buildings, different priorities. Sometimes in this job I feel as if I'm on the edge of everybody's priorities because everybody has their own set of targets to reach. And sometimes the targets for different organisations actually work against each other (H, 9/421).*

> *Yes I think that if people aren't used to working together perhaps aren't necessarily understanding of each other's roles, maybe not respectful of each other's roles then sometimes there can be quite a lot of challenges in taking that*

> *forward. I think that there needs to be a greater understanding really of the key components that you need to put together really to ensure that that happens, that people do get together and work well together…It does take time to facilitate that and to ensure that people have an understanding of, I suppose, the diversity really that that brings…People perhaps don't feel that they're in a comfort zone anymore and they're sort of disengaged from that and feeling a little threatened* (M, 12/595).

The first quote referred to above, has already been cited in the thesis. In the spirit of complexity it is included again, with reference to collaboration, to demonstrate the patterning and reoccurrence of particular issues and the inter-relatedness of emergent themes.

Some respondents, specifically those already involved in partnership working, recognised the importance of the economy of power and that obfuscation can actually disempower:

> *It's about equalising the relationships so that everybody understands what it all means and that in some cases means bringing some members up and actually dragging some partners down to get that equality* (J, 9/402).

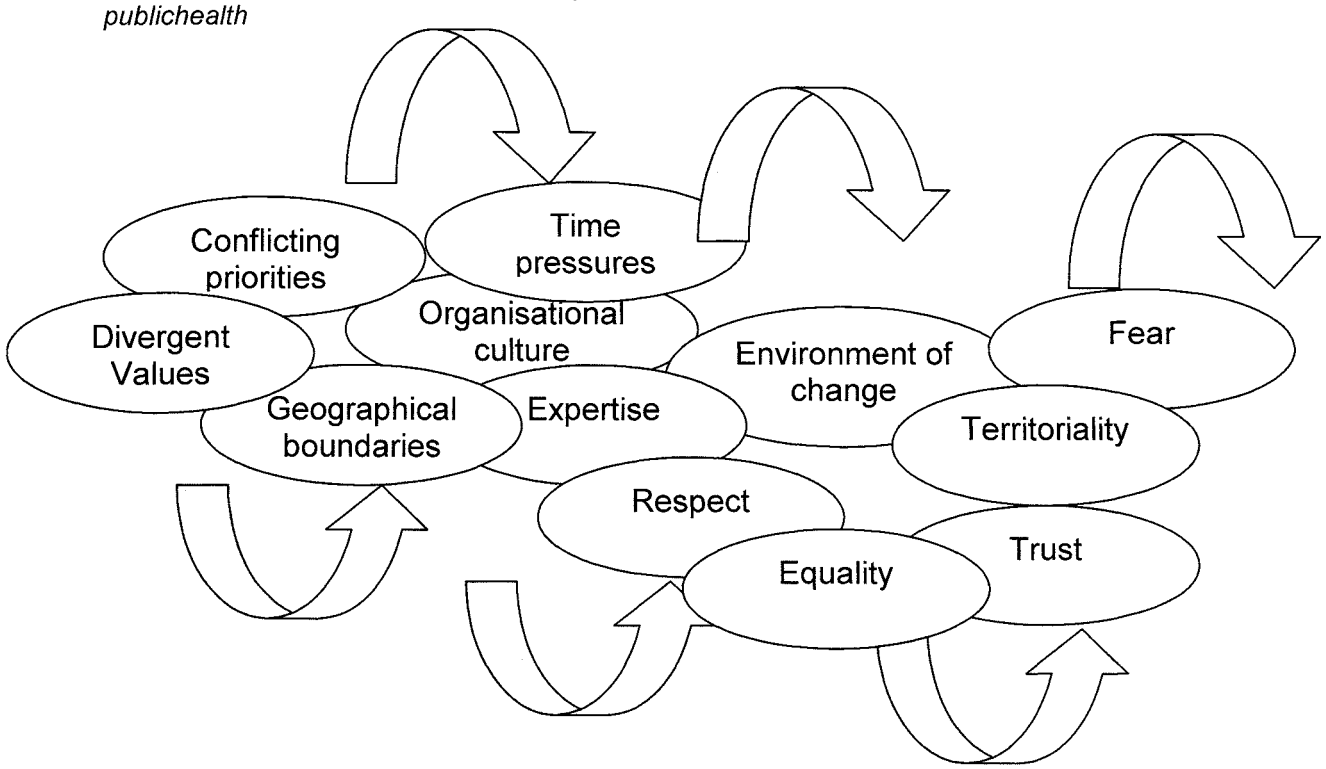
Interestingly one respondent suggested that the technocratic nature of GIS does not fit with the culture of collaboration:

> *Yes exactly, the culture. There's a culture of, research used to be very valued, pilot studies were valued, audit all of these things were valued and now…And expertise, technical expertise was valued and the current culture is very much about generic skills, everybody being able to do a bit and inclusiveness. Once you get inclusiveness something like GIS isn't there* (W, 4/169).

There was some correspondence between participant's responses and the barriers suggested by Naidoo and Wills (1994) regarding collaboration (Chapter 2, Table 2.3). For example, common themes emerging in the interviews included the challenges regarding discordant priorities, contrasting value systems, territoriality, professional rivalry and geographical boundaries.

Respondents grasped that just because groups claim to be working in partnership it does not mean that they necessarily do so in practice. To foster a truly inclusive approach to GIS data representation and joint working, 'lay' people could be consulted and asked to suggest which indicators would be meaningful to them. Their input could then be used to guide data collection and ultimately to drive the mapping exercise.

Figure 7.3: The multiple and contingent barriers toward effective collaboration in publichealth



7.7.2 Discussion of collaboration debates

All participants interviewed understood the importance of collaboration and working together at a theoretical level and data sharing was felt to be pivotal in contextualising the debate. Several examples of partnership working were volunteered. Overall there was a feeling that despite data collaboration being a noble and worthwhile goal, a plethora of barriers existed to prevent full engagement in the process. The usual problems of territoriality, defensiveness, cultural differences, organisational priorities, confidentiality and data sensitivity were cited. The complexity of partnership working was well articulated where competing drivers and resistance to change thwarted the development of successful and sustainable collaborations. Notably one participant argued that the technocracy of GIS would actually work against its use in interagency working. This deviant case will be explored further in chapter 8.

7.8 Conclusion

There was a relation between GIS status and data origins whereby the epistemological and ontological positions of individuals impacted on how they perceived GIS. The way individuals shape reality and measure phenomena seems to be influenced - at least in part - by the culture, priorities and value systems of the organisation for which they work. The importance of individual

experience, tacit knowledge and beliefs should not, however, be undermined. Decision-makers with a sound understanding of GIS principles valued the analytical functions, whereas those with less experience of GIS saw its value in terms of data presentation and communication. GIS was commended by a practitioner working in the field of health protection, for the way in which mapping demonstrates aspects of time and place (salient notions of any public health issue) are explicitly recognised and presented. A number of medical decision-makers appreciated the potential analytical power of GIS. Conversely, environmental and community decision-makers saw the value of GIS in data storage, management, presentation and communication.

Many limitations of GIS were concerned with the data input into the spatial mapping packages such as data quality, availability, access and disparities in boundaries. Other concerns included licensing, compatibility of packages, training and organisational infrastructure. Finally in terms of maps as evidence, GIS outputs were acknowledged to be *"accessible", "seductive" and "memorable".* Some respondents believed maps to be a democratic means of communication but equally a number of participants saw them as technocratic and confusing.

Understandings of the concept of public health were concordant with contemporary definitions. Participants grasped the complex, multi-faceted nature of public health and acknowledged the significance of understanding the intrinsic linkages and connections between related domains. Subtleties existed in definitions employed by respondents for example: mapping versus GIS and data versus information. Perceptions of maps and mapping technology were shaped by organisational values as well as individual experiences and beliefs (data origins impacts on data status). Respondents had knowledge of mapping concepts and a sound understanding of GIS even in the absence of first hand experience.

There was a dichotomous split between NHS orientated decision-makers and those with a less biomedical remit. Decision-makers in the NHS service sector tended to focus on interventions and uptake rather than processes, whilst stakeholders involved in the environment and community sectors were more articulate about their feelings regarding the maps. Individuals tended to be more enthusiastic about GIS if they had positive experiences of using GIS systems in the past. In complexity terms, such experiences might be referred to as attractors. Respondents could not easily be divided into protagonists or

antagonists as such. Rather than explicitly labelling participants, openness to GIS technologies was viewed as an attractor within the paradigm of complexity. Most interviewees were aware of both the advantages and disadvantages of maps as evidence. It seems to follow that because GIS is an accessible tool for data display it would be well suited for use in public health practice due to the diversity of practitioners and audiences alike. The themes and inter-relations discussed here will be explored and related to the broader literature base in the next chapter.

"Think like a wise man but communicate in the language of the people"
(William Butler Yeats, 1940).

Chapter 8: Discussion

8.1 Introduction

The discussion chapter seeks to integrate the key themes, concepts and findings from each of the chapters presented in the thesis. Due to the explicit boundaries of the thesis, discussion has been limited to the use of complexity theory in understanding how GIS can contribute to public health decision-making processes. How the study findings relate to the contemporary literature base will be explored. The case study uses complexity theory to examine decision-making pathways in public health, thus each of the sections are viewed through the lens of complexity. Four discourses were identified through analysis of the findings: the ontological, power, functionality and collaboration discourses. By drawing together key aspects of the study and reflecting on how the study findings have addressed the original objectives, this chapter aims to develop understanding of how GIS can contribute to public health decision-making in the real world.

The chapter begins with a critical discussion relating to the complexities of the public health landscape and the multiple realities of public health by drawing on the ontological discourse uncovered through empirical analysis. The next section debates the contours of complexity in evidence-based decision-making processes by returning to the power discourse. The functionality discourse is then explored and questions relating to the uptake of GIS are addressed. Discussion moves to focus on the key public health concept of collaboration in an examination of the extent to which such a complex data system is accepted by the public health community and how GIS can potentially contribute to sharing intelligence. Finally, consideration returns to the case example, childhood lead exposure, in a reflective exploration of the dimensions of this complex and timely public health issue.

8.2 Complexity and public health

This thesis examined the value of geographical information systems in public health decision-making using a complexity approach. Initially the central aim of the study was captured as the following:

Through the use of the case study approach the project aims to explore how GIS data can contribute to the evidence base for decision-making in contemporary public health. Childhood lead exposure represents the case example within the context of Newcastle upon Tyne.

To achieve this overarching aim the following objectives were devised and adapted:

1) Produce visual representations of potential childhood lead exposure by mapping discrete environmental and demographic datasets using GIS. Through objective 1 understand the principles and nuances of the GIS toolbox and develop stimulus material for debate with decision-makers.

2) Conduct a series of semi-structured interviews with decision-makers in agencies whose work impacts on the public's health to unpack their thoughts, perceptions and beliefs concerning the value of GIS in public health.

3) Through analysis of interview transcripts examine and explore:

- the status of GIS as a tool within public health organisations;
- the value of GIS map representations in the evidence base for decision-making;
- the use and possible misuse of maps as evidence;
- the potential of GIS to act as a vehicle for information sharing to facilitate inter-agency collaboration.

As the study progressed and the initial data were analysed complexity theory emerged as a navigational device to make sense of the research findings. The introductory section reiterates the usefulness of the complexity framework in the field of public health and re-emphasises its fit in the context of this study.

8.2.1 What's complex about public health?

Public health transcends boundaries. It effects and is affected by a plethora of social, cultural, economic, political and environmental factors. Inter-relationships between health determinants are contingent and non-linear (see section 3.4). When considering health as a complex adaptive system, the dynamics are often unpredictable and chaotic (for example, the intricacies of smoking behaviour: smoking cessation in a long term addict can actually lead to ill health relating to inabilities to cope with stress [Niaura *et al.*, 2002]). Another pertinent example demonstrating nonlinear relations in public health systems

involves vaccination strategies; the utilitarian ethos behind immunisation is to ensure that enough individuals are immune to a particular disease in a population to bring about herd immunity or even eradication, in the case of smallpox. In a way, the thinking behind such a strategy is paradoxical (Rose, 1985) as the benefit evoked from such a process confers an advantage to the collective rather than the individual and the process might be at odds with individual concerns and anxieties or with religious and cultural beliefs.

Current government thinking states that contemporary public health interventions should consider distal outcomes, not just quick wins, and bottom up approaches are to be endorsed ahead of top down, paternalistic strategies (Acheson, 1998). Raphael (2000), however, contends that many health professionals still visualise health as the absence of disease and focus their work on an individual rather than population level. The biomedical model remains embedded in Cartesian reasoning and many practitioners continue in their quest to determine causality by drawing on evidence from quantitative, experimental studies based on linear and mechanistic models of understanding.

Complexity offers a pragmatic alternative to the monotechnic and myopic public health approaches characteristic of the Newtonian past. Modern public health is necessarily complex in praxis as central government endorses ownership of public health beyond the preserves of the NHS. Government rhetoric looks to organisations outside of medicine, such as the local authority, statutory, voluntary and community organisations (Shaw, Ashcroft and Petchey, 2006) to contribute to protecting and promoting population health. Collaboration and inter-agency working is therefore critical to successful public health practice in the 21st Century.

Goldenfeld and Kadanoff (1999) and Geyer (2003) draw attention to the proliferation of complexity theory applications in both the natural and social sciences. Little discussion has been given, however, to the application of complexity theory in public health discourse. The ideas of complexity can be applied to just about any system ranging from European Union social and economic policy (Geyer, 2003) to decision-making at the individual level by diabetic patients (Wilson and Holt, 2001). According to complexity theory the aim is to shift the frame of reference so that the system becomes adaptive and stays within reasonable boundaries (Geyer, 2007). The complexity lens

provides an epistemological viewpoint which is in keeping with public health in the following ways:

- complexity theory considers public health as a multi-faceted system with contingent parts and non linear inter-relations;
- complexity discourse goes against traditional reductionist thinking;
- complexity approaches are flexible;
- complexity thinking crosses boundaries to enable collaborative working.

In the past public health initiatives have reacted in a linear fashion to respond to an emerging problem. In contrast complexity theory provides a template for developing initiatives, which plan for rather than react to imposed changes on the system and are broad ranging and adaptive and therefore sustainable. Based on this template decision-makers are encouraged to look at the effects of an intervention on the system as a whole especially those groups which are disproportionately affected by health inequalities. The case example of childhood lead exposure is considered from a complexity perspective in detail in section 8.8.

8.2.2 The multiple realities of public health discourse

The archetype of modern public health is as an inherently pluralistic discipline (Naidoo and Orme, 1998), which draws on a variety of methodological approaches and epistemological positions (Kelly, 2006). Williamson (2004) argues that power struggles between the medical and non-medical factions of public health have been borne out of a concealed need to keep public health 'pure' by bringing it back to its biomedical roots. Indeed, many of the narratives recorded during qualitative data collection were consistent with such observations, with many interviewees from NHS organisations advocating the use of GIS to examine causal associations in line with the positivist paradigm. Several individuals suggested potential uses of GIS in epidemiology and one respondent contested the validity and usefulness of the mapping report because it failed to demonstrate causality.

In keeping with the shared values and principles of public health thinking is the pivotal notion of collaboration and partnership working. Respondents agreed - theoretically at least - that GIS provides a vehicle to draw together an array of evidence to understand the multi-faceted and complex nature of public

health problems. GIS can, potentially, be used to accommodate a multitude of disparate voices that visualise the issue of concern from varying and sometimes opposing perspectives.

During exploration of the ontological/data origins discourse, the importance of background, different knowledge, experiences and belief systems were all seen to shape how an individual sees and knows the public health world. It was clear that participants from different organisations had varying ways of knowing, seeing, measuring and understanding. Accordingly there were notable differences in how participants valued GIS, which seemed to be influenced by individual beliefs and assumptions, organisational didactics and inter-agency politics.

These differences were explicit at the organisational level also: those in the environment sector and also those in academia were naturally familiar with the notion of mapping and considered GIS in a variety of contexts while those in the NHS were keen to fit GIS into an analytical role. Conversely, those within the community domain were positive about the notion of mapping and embraced the idea of GIS for data integration purposes. Clearly, each of the agencies had differences in terms of history, priorities, objectives and structure that mediated respondent's thoughts, attitudes and perceptions regarding GIS technologies. Multiple and disparate realities exist in the public health arena due, ultimately, to the multifaceted nature of the discipline (Kelly *et al.*, 2006). This is necessary and ultimately beneficial but can create boundaries and barriers to effective partnership working.

An organisational model of complexity would suggest that to move forward, these multiple realities should be acknowledged and accepted in an attempt to find common ground and to forge a way ahead. Pluralism is a popular construct in contemporary public health thinking and the idea of giving credence and equality to all voices regardless of their power base is central to partnership working (Heenan, 2004). Following from the ontological discourse, discussion moves on to focus on the notion of power: the power of maps and the use and potential misuse of GIS in decision-making.

8.3 Aspects of complexity relating to GIS mapping in public health decision-making

The notion of evidence-based decision-making bridges the ontological and functionality discourses as evidence-based thinking is inherent in the fundamental precept endorsed by New Labour of 'what matters is what works'. The following discussion reflects on the complexities of decision-making in public health and offers critical debate on whether or not GIS maps can be used as valid and meaningful sources of evidence. The constructs of complexity are used as section headings to draw together the study findings and to make connections with the contemporary literature base.

8.3.1 Elements of order and disorder in decision-making

In the 21st Century decision-making is neither a predictable nor a linear process. Evidence-based approaches attempt to find the best and most relevant evidence to answer appropriate questions, in a judicious manner, in real time (Leon *et al.*, 2007). Decision-making in public health is a complex system involving rational and technical reasoning but also unpredictables and a zone of disorder characterised by diverse opinions, discordant priorities, competing personal interests, limited resources and a changing political climate within and out with an organisation. The situation is complicated further when more than one agency is involved. Unlike clinical decision-making, which focuses on the individual, decision-making in the public health milieu involves determining the best course of action or intervention at a population level. Some factors can be controlled, others are unpredictable and not amenable to external factors; but all are inherently political. Competing ideologies may come into play regarding the action to be taken or the intervention to be made, the organisation or actor who intervenes and who pays.

Decision-making in the real world takes place in non-homogenous and often politically charged environments. Brownson and co-authors (2003) endorse the view that decision-making is mediated by a multiplicity of factors such as knowledge, experience, skills, guts and flair. Moreover, situational variables such as opposing working cultures and organisational ethos, inter-organisational politics and government rhetoric all interact to affect the economy of power and thus impact on how the system functions to generate decisions.

The idea that evidence is the only driver in public health decisions is naïve and overly simplistic (see figure 8.1).

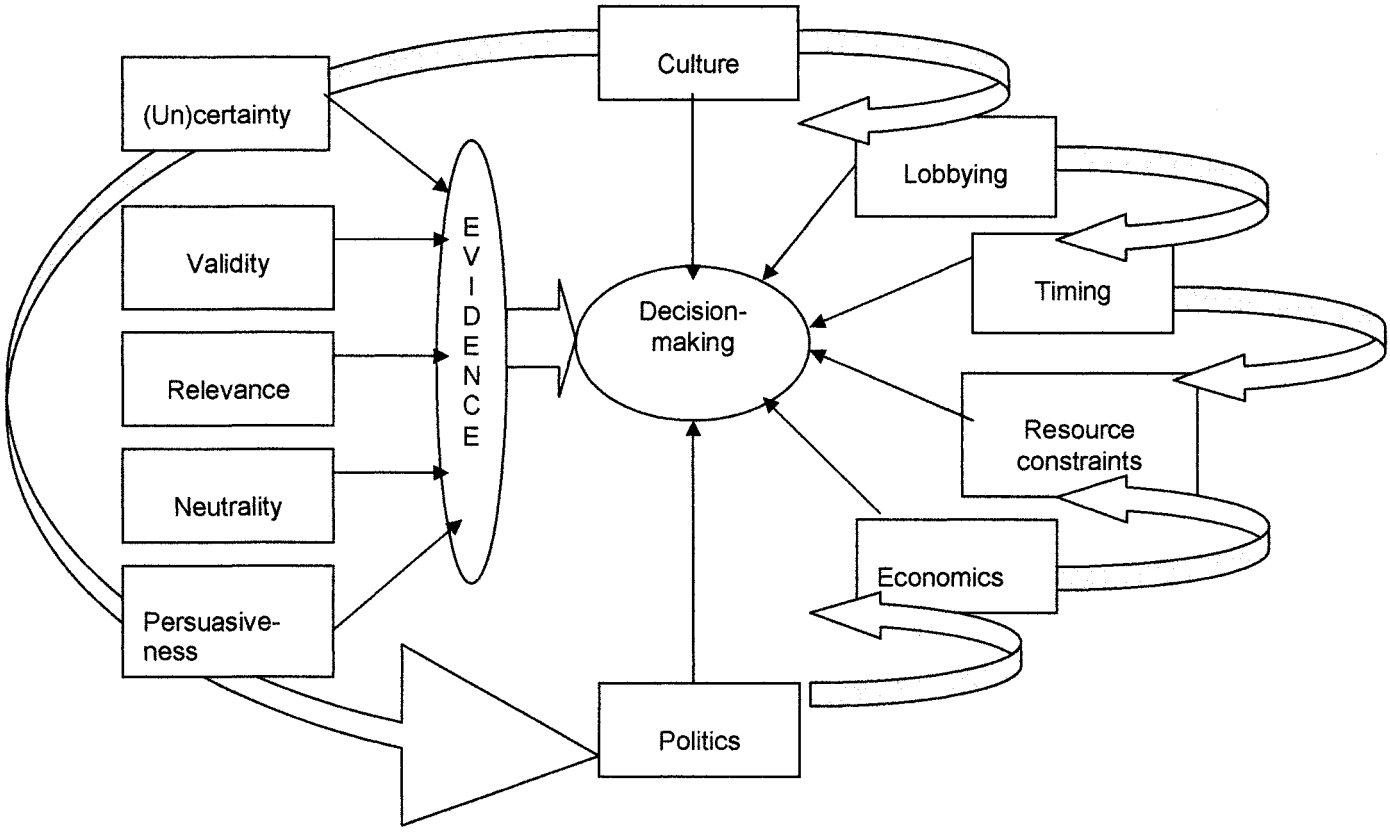
A range of models of decision-making was noted. First, the paternalistic model whereby those with the power decide what to tell and what not to tell with respect to the intelligence base and decisions can be potentially biased as knowledge is the preserve of a small group of elite. This model is in direct competition with the fundamentals of complexity where the idea of not taking action just because a problem is too complicated is refuted. Second, and in direct contrast, the bottom up community model of decision-making is embraced by public health practitioners and there may be a role for GIS and maps for all within this paradigm.

Partnership decisions seek to reconcile a multitude of disparate voices, incorporating ideas from different communities with varying organisational cultures, histories and priorities. The actors in such pathways come from various niches: some are more technologically aware while some have a keener appreciation of public health issues whereas others have a clear understanding of organisational dynamics. These understandings were reflected in the purposive sampling framework of the study, whereby individuals with both technological nous and public health awareness were included. Attempts were made to value interviewees equally, regardless of their position, status, background or skill set but due to the researcher's role in the interview dialogue and the inherent biases that accompany the process, such attempts are far from straightforward. In contrast to quasi-experimental data collection, the complexities of the interview scenario make it difficult to neutralise or control for bias. In this way, complexity theory provided a platform for multiple, and often conflicting, voices to be heard.

There is some debate in the literature regarding the value of evidence-based practice, particularly in medicine. Upshur (2002) questions the need for an *evidence base* in medical decision-making. Similarly, Sweeney (2006) highlights the importance of experience and tacit knowledge in decision-making processes in the context of general practitioners, whilst remaining true to the evidence-based paradigm. Participants in the study appeared cognizant of the importance of not just what the evidence says but how it says it or in other words how the evidence or information is presented. This finding is congruent

with Tufte's (1990) arguments regarding the potential of data containers to clarify or distort data interpretation.

Figure 8.1: Decision-making as a complex system: factors influencing decisions (adapted from text in Brownson, (2003) and extended using study findings)



8.3.2 Emergence: the use of GIS in decision-making

Since the seminal spatial study by John Snow demonstrating the transmission of cholera, public health practitioners have recognised the fundamental importance of place in epidemiological enquiries. An understanding of the spatial distribution (and transmission) of infectious, chronic and environmental disease as well as public health indicators such as infant mortality, life expectancy and other measures linked to inequality is paramount. It follows, therefore, that GIS applications and maps as evidence have an important place in contemporary public health decision-making. In this case study, participants acknowledged that maps were a valid means of evidence ifproduced and used judiciously.

Raphael (2000, p.357) observes:

> *Evidence reduces uncertainty in decision-making. Evidence is about reality, about what is true and not true. The nature of reality itself, however, is the basis for continuing debate in the social sciences, less so in the health sciences. Consensus is being reached within the traditional health sciences and in the health promotion field of what constitutes evidence, but with little congruence between these fields. Are there the makings of a paradigm war?*

In accordance with Raphael's assertions the ontological and power discourses highlighted differences in how interviewees 'saw' and 'valued' GIS map representations as evidence. Decision-makers in environmentally focussed organisations were more familiar with maps and tended to see them as a valuable presentation and communication tool. Obviously the organisational background, their knowledge, experiences and belief systems affected how they see, know and measure reality. Likewise stakeholders from the community domain tended to view maps as pictures or objects that they could relate to because they were accessible and immediate.

NHS practitioners with expertise in quantitative methods were keen to apply GIS technologies in an analytical capacity, possibly in an attempt to make GIS science fit their own world-view. It follows that the underlying values and belief systems of participants influenced the extent to which they engaged with the notion of maps in decision-making pathways. These interpretations correlate with findings from an empirical case study examining how NHS decision-makers use evidence (Elliott and Popay, 2000). The authors found that research is open to multiple interpretations

> *shaped by the personal and professional values of the interpreter and by the social contexts within which the research findings are to be applied* (Elliott and Popay, 2000, p.467).

They conclude that there is a need to understand the implicit assumptions underlying different interpretations

Under the theme of communication, is '*misinterpretation*' of GIS maps in fact a misnomer? Within the complexity domain all interpretations are equally valid. Just because people see maps differently from the map maker does not necessarily mean that their interpretation is wrong; rather, one map can initiate a range of different but equally valid map interpretations. Similarly the actual process of map making can produce a range of different outputs from the same original data. In Monmonier's words:

> *A single map is but one of an indefinitely large number of maps that might be produced for the same situation or from the same data* (Monmonier, 1996, p.2).

To what extent community decision-makers would trust map representations as sources of evidence could not be fully ascertained in the interview discussions. On the surface they seemed to be positive about the use of maps in decision-making, but by framing maps as 'pictures' they may be less inclined to base decisions on what might be referred to as 'flimsy' evidence (see section 7.5.2). Additional qualitative work, perhaps in a participatory workshop setting, is necessary to explore this proposition further.

The power discourse suggested that problems were likely to arise when communicating evidence to diverse audiences whose world-views are different and who value different types of evidence (refer to section 7.4.1). In accordance with these thoughts Raphael (2000) foresees difficulties regarding satisfying the evidence requirements of traditional health professionals who value the experimental or quantitative model of public health. Conversely, maps were felt to be important vehicles for communication: they were described as *"accessible", "immediate", "engaging", "emotive"* and *"seductive"* (see section 6.3.3) and for these reasons they might be able to transcend the traditional boundaries between the various epistemological viewpoints in public health.

Most of the sample group did not believe that GIS map representations fit with the hierarchy of evidence. This suggests that respondents valued a broad ranging or eclectic approach to evidence-based policy and practice. Participants seemed to understand the need for pluralism and used phrases such as 'horses for courses' when talking about the suitability of different methodological approaches. Despite a significant number of decision-makers being trained in the positivist tradition of quantitative, measurable evidence few tried to translate the hierarchy of evidence onto the GIS approach. This finding conflicts with earlier suggestions that a number of biomedical decision-makers were keen to apply GIS in an analytical capacity to comply with the demands of epidemiology and cause and effect thinking. Moreover, these findings raise the difficult question of whether GIS is a methodology at all. This proposition is considered further in section 8.4.1.

8.3.3 Maps as attractors in decision-making pathways

Maps articulate the spatial dimension of an issue and GIS mapping approaches have the potential to cut through the dynamics of a problem by introducing a temporal element. The functionality discourse illuminated how maps were framed as evidence rather than simply aesthetic objects. A number of respondents felt that maps were more than just 'pretty pictures'. This finding is commensurate with doctoral research by Dorling (1991), whose thesis argues that mapping enables visualisation of the real world, which in turn can facilitate the emergence of new insights and understandings. Dorling draws parallels with the translation of data into visual images and the practice of the visual arts. The GIS maps in this study were thought to be powerful, provocative, immediate, and thought provoking. By avoiding the complexities of language, maps were felt to be accessible to all and a democratic means of communication. The potential of maps for communicating complex information fits with Liam Donaldson's challenges for information display:

> *Strengthening public health means that we need to aspire, we need to explain, we need to communicate. We need to create a commitment to change and spelling out the health challenges powerfully and imaginatively helps to create that impetus* (Donaldson, www.dh.gov.uk)

Beliefs contributing to the positive acceptance of maps as evidence in the study centred on the power of pictures to communicate rather than words. Maps are intuitive. Maps reflect the dimensions and shape of an issue in an immediate and accessible manner. As the interviews demonstrated people also relate very well to maps as they are familiar – individuals have grown up with maps, they see maps in everyday life, for example in weather forecasting and transport systems. Dorling (1991) suggests that engaging with data in a visual form such as a map enables a "*more open-minded style of analysis*" which "*exploits the visual sense we are naturally best equipped to learn from*" (Dorling, 1991, online thesis). The data collected from public health decision-makers in this study seems to be consistent with such observations. Maps can enable an audience to see the full extent of a public health concern by introducing the important and anchoring dimension of place. They have the power to speak to an audience in a way that tables and graphs cannot. These findings parallel the observations of Edward Tufte (1994) who argues that just as tables of data are linear, rigid and one dimensional, figures (and accordingly maps) "*...work at the intersection of image, word, number and art...seeking to reconcile data with doctrine*" (Tufte, 1994, p29).

The idea that different people take different messages from a map can help to engage the whole audience but the corollary is that this may enable misinterpretation and individuals taking confused messages from the GIS data representations. The consequences of misinformation can be massive as Michael Crichton speculates in a speech at the Washington Center for Complexity and Public Policy (2007). He comments on the significance of inaccurate and spurious information given to the victims of the Chernobyl disaster:

> *But most troubling of all, according to the UN report in 2005, is that "the largest public health problem created by the accident" is the "damaging psychological impact [due] to a lack of accurate information [manifesting] as negative self-assessments of health, belief in a shortened life expectancy, lack of initiative and dependency on assistance from the state" In other words, the greatest damage to the people of Chernobyl was caused by bad information.*

The consequences of erroneous information and misunderstandings can be negative, long lasting and dangerous. It is clear that when using GIS maps as evidence, data analysts and managers as well as GIS users have an important role in displaying information judiciously (refer to section 7.4.3).

In accordance with several GIS authors (Järup, 2004; Monmonier, 1996) display of the mapping exercise demonstrated that data can be distorted through use of inappropriate administrative boundaries and erroneous conclusions can be drawn through spurious associations implied in maps overlays (refer to section 7.5.6). Järup (2004) suggests that these problems could be surmounted through the substitution of administrative boundaries with a standard grid square in data analysis.

Tufte (1990, p.48) describes his philosophy of information design as *"self-effacing displays intensely committed to rich data"*. Tufte's notions of simplicity and contradiction in data display correspond with the polar opposites of order and disorder in the complexity paradigm. Similarly, individuals engage with maps because they can individualise, personalise and relate to different areas or attributes within them. This parallels Tufte's ideas about micro and macro readings within a display, or stories within stories. Metaphorically, the concept of stories within stories and micro and macro information is in keeping with the idea of nested systems with non-linear behaviours in complexity thinking. In personalising maps, individual viewers will make different interpretations and take varying inferences from the data displays.

Several decision-makers expressed concerns regarding over-crowding in the GIS map displays (see section 6.3.8). Tufte, on the other hand, argues that 'data rich' representations enable the audience to add meaning or narrative to the dataset in order to personalise the data in accordance with their own views, aims or end points. Hence *"control of information is given over to viewers, not to editors, designers or decorators"* (Tufte, 1990, p.50). Conversely, representations sparse of data can render the audience passive and uncaring if they do not believe in or relate to the information presented. The notions of apathy and disengagement relate to the key concepts of community engagement and empowerment in modern public health thinking.

Effective public health policy should be driven by community and stakeholder demands, it should be bottom up rather than top down and should serve to empower rather than disenfranchise those affected by inequality. In summary, Tufte (1990) argues that there is an optimum ground between the micro and macro picture, between data overload and data dearth and between simplicity and complexity. He contends that simplicity does not equate to clarity, in fact quite the reverse: rich and contextualised data are more likely to bring about coherent understanding. Tufte's ideas about data display seem to correspond to his understandings about the real world:

> *...the deepest reason for displays that portray complexity and intricacy is that the worlds we seek to understand are complex and intricate...* (Tufte, 1990, p.59)

With a small number of exceptions (specifically those who have worked in an academic role) interviewees tended to be unaware of the growing body of literature involving GIS and health. Such research continues to be siloed into the environmental sphere despite the emergence of journals such as *Health and Place,* which have little dissemination in the public health world.

8.3.4 Elements of paradox: is GIS a technocratic or a democratic tool?

Dorling (1991, online thesis) observes that *"maps and charts, by containing information, have always been a key to power and social control"*. Despite participants being aware of the potential of GIS maps in public health and understanding the underpinning science, use of GIS remains limited, confined to traditional uses in specialised micro-environments within organisations. In some cases the findings from the data status discourse suggested that decision-makers might not have wanted to engage fully with GIS for fear of information becoming

available to a wider domain. Data owners may not want data to be translated into maps that are accessible and understandable by all. Brownson *et al.* (2003) suggest that new therapies are suppressed by the establishment because they are expensive or unconventional. It is possible that GIS falls into the same category and may be actively suppressed for covert reasons.

According to Foucault (1972), knowledge is power so it follows that to secure a power base it may be necessary to hold onto information and to prevent it from being disseminated more widely. Similarly, organisations may not want to share information because they are protective over their own patch. Senses of territoriality, fear and insecurity were picked up particularly from NHS related decision-makers affected by change and reform. A number of respondents from NHS organisations (refer to section 7.7.1) were precious about what they perceived as their territory or domain and in some cases seemed reluctant to embrace change. Similarly, Carey and Smith (2007) suggest that attempts to transcend disciplinary boundaries can engender a sense of fear and feelings of being undermined and threatened.

Some of these explanations could be encapsulated under the term subterranean knowledge (Weir, 2007), which refers to information hidden or concealed. This type of knowledge is notoriously difficult to access because it places the respondent in a difficult (and sometimes culpable) position. In the context of public health, honest and open responses about the use of GIS and data sharing might render the respondent accountable for failing to embrace government rhetoric regarding 'joined-up thinking' and collaboration.

In keeping with the notion of multiple map realities and in line with the findings from this thesis, MacKian *et al.* (2003) present the case for multiple interpretations of maps by drawing attention to differences in who interacts with the map including stakeholders from central government, general practice or the social services. The authors assert that there is no 'right' interpretation or correct answer and that each version has equal status and can contribute to the 'composite picture'. Modern public health is all about social justice and empowerment, therefore credence should be given to all map interpretations to enable multiple and disparate voices to be heard. Disagreement should not, therefore, be regarded as a negative position. Instead it should be reframed as a means of broadening understanding of the issue in an attempt to effect sustainable change. Complexity offers a way to negotiate through a difficult and

thorny landscape where GIS and maps could easily be dismissed because there are potential fallibilities. By drawing on the precepts of complexity these potential limitations can be seen in a different guise: the issue of discordant interpretations relating to map displays should be invited as they can be viewed as a tool for community development, collaboration and empowerment. To quote Yeats (Yeats, 1940), GIS mapping can provide the potential to "*communicate in the language of the people*".

8.4 The functionality of a complex tool in a complex environment

As MacKian *et al.* (2003) recognise, in order for mapping to be used to its full extent, that is as a 'theory-building tool' rather than in a purely descriptive capacity only, maps should be used more flexibly and the assumptions between representation and reality made explicit. The use of GIS as a tool in public health is discussed in the following section. Drawing on the functionality and power discourses, key findings are discussed in relation to the complexity of public health policy and practice. Issues around practicalities, data dependency and maps for communication are dissected and related to the contemporary literature base.

8.4.1 GIS – a bridge or a chasm in public health discourse?

Interviewees were positive about the value of GIS in public health practice but many were quick to express that it was not a panacea, a cure all or a wonder tool that could be used to understand or explore every potential public health problem. Haque (2001, p.259) suggests that GIS can:

> *...provide unparalleled power to examine social, economic and political circumstances. In essence GIS is the best technology to understand and solve problems related to place and space.*

Questions around the functionality of GIS in the public health arena were framed through the complexity lens:

- Can GIS be used as a practical tool in public health decision-making?
- Is GIS a methodology in its own right or merely just a method?
- Does GIS contribute to rationality and reason or does it, because map presentations can evoke emotion, cause disagreement and chaos?
- Is disagreement always a negative position?

- Can maps communicate democratically despite GIS being a technocratic tool?
- Is it a better strategy to increase uptake of GIS to all or to enhance the provision of specialist expertise?

Each of these questions will now be addressed in turn.

While GIS was perceived as a complex and sophisticated toolbox the underlying logic of spatial display of information was well understood by all of those interviewed. Respondents agreed that GIS was a valuable tool but only in the right circumstances. The notion of 'fitness for purpose' percolated though many of the narratives, see section 7.5.3 for example. Dunn and co-workers (2007) reiterate the importance of choosing the correct analytic tool to address the question of interest to provide robust and coherent evidence on which public health practitioners can confidently make decisions. In an earlier study Dunn and co-workers (2001) showed, using a survey approach, that choice of method may be influenced by tradition or familiarity more than the dynamics and detail of the issue itself. In conclusion, Dunn and co-workers argue for continued espousal of the multi-disciplinary approach to health and environment related issues.

The critical importance of good quality data highlighted during the interviews corresponds to comments by Haque (2001) on data limitations including unwillingness to share data, lack of resources to fund data collation and conflicting data formats. It is important to note that this concern about data quality is not just a limitation with GIS technologies but with all other forms of data representation and analysis. Indeed, Raine, Godden and Mckee (2006) cite five critical issues relating to the provision of information and intelligence for public health as follows:

- incomplete recoding of data;
- access to standardised data;
- consistent data collection across agencies;
- anonymisation to enable data sharing between agencies;
- emphasis on the importance of good data and intelligence systems to facilitate compliance to systems protocols.

Haque (2001) argues that the advantages of GIS are explicit: expediency in data access, effective dissemination of information and efficiency in policy implementation. As Mennecke (1997) asserts, however, while the positive

societal impacts of GIS are multi-fold there is potential for negative effects relating to error propagation, privacy and disclosure and misrepresentation of information. GIS can be a useful checking mechanism enabling engagement even if it is used to contest what is published or assumed to be true.

Quantitative scientists often employ GIS as a tool but equally - as this study has demonstrated - GIS can also inform the qualitative debate. This leads to the question of who will lay claim to GIS as the dominant tool within their research tradition? Indeed, does GIS have to belong to any one discipline? Or can it be used as a method across disciplines? Such concerns resonate with the territoriality debates visited earlier in this chapter (see section 8.3.4) and the dominance of positivism. Wright, Goodchild and Proctor (1997) examined the debate around the meaning of GIS (tool or science) using electronic discussion lists, which transcend traditional academic boundaries. They identified three different concepts of GIS: (1) tool, (2) tool making and (3) science and suggested that GIS should be thought of as representing a 'fuzzy' continuum between tool and science. In conclusion, the authors suggest that GIS does not conform to a particular philosophical position and should not be siloed into any one methodological approach:

> *GIS may represent a new kind of science, one that emphasizes visual expression, collaboration, exploration, and intuition, and the uniqueness of place over more traditional concerns for mathematical rigor, hypothesis testing and generality.* (Wright, Goodchild and Proctor, 1997, p.360)

This conceptualisation is in keeping with the complexity paradigm and refutes the suggestion that GIS is the exclusive preserve of positivism. As Wright, Goodchild and Proctor (1997) contend GIS has social extensions: the power to deliver messages and to communicate and the capacity to empower communities into action. In this study it was difficult to ascertain whether or not it was the actual GIS maps that evoked emotion or whether it was the issue that the maps represented, that is childhood lead exposure (see for example section 6.3.9 and section 7.5.5).

The interviews yielded complex narratives encapsulated by the apparent conflict between the themes of technocracy (of GIS) and democracy (of maps as evidence). In essence GIS is a technocratic tool since it requires expertise and experience to be used to effect. Technocracy is defined as

> *a system of governance in which technically trained experts influence society by virtue of their specialised knowledge and position in dominant political and economic institutions* (Meynaud, 1969 cited by Haque 2001).

Haque (2001) is quick to note, however, that the expertise required in GIS applications could actually be a barrier to democratic use leading to a loss of public control where power would return to those in possession of GIS knowledge, the technocrats.

> *As computers have become widespread average people will use information to amplify their voices in matters related to their own governance. GIS will be seen as a liberator of socially and politically marginalized groups and as a source of democratizing power for the newly networked groups. If information is power in this sense, and if community is built through dialogue, then GIS permits both to emerge for those who would otherwise have no voice and no space for collective action* (Haque, 2001, p261).

Sharing of knowledge and spatial data is therefore crucial for GIS to become a truly democratic tool.

8.5 The complexity of collaboration

Section 5 draws together the conceptual findings relating to the fourth and final discourse: collaboration. Readers should refer to section 2.3.4 and section 3.8 for a discussion of aspects of collaboration in public health practice. Building on the property of maps to communicate and provide information in an immediate and accessible fashion and the capacity of GIS to share and integrate data the use of GIS in collaborative partnerships is explored. Putative barriers to effective partnership working are examined in relation to existing knowledge and understanding.

8.5.1 Collaboration as an open system with contingent relations

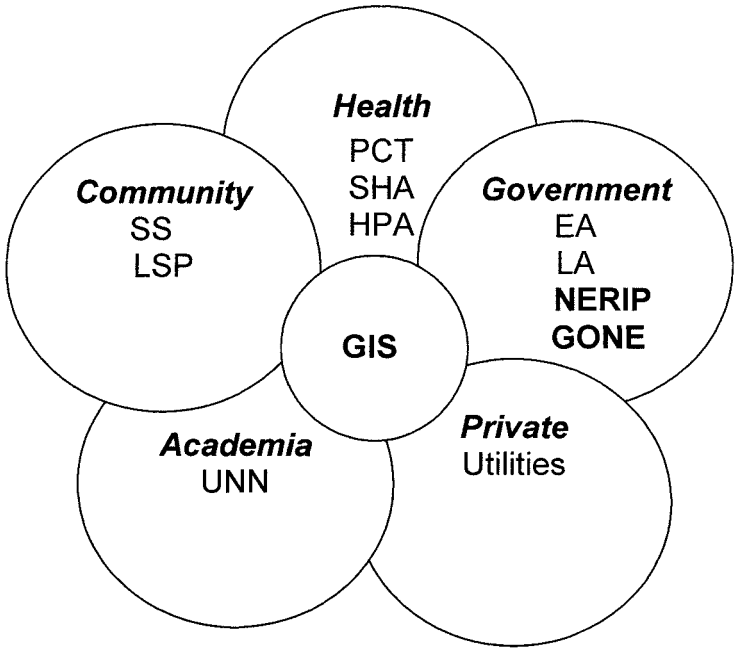
In line with findings from a study examining partnerships for health improvement by Shaw, Ashcroft and Pushey (2006, p.83) respondents noted the importance of developing relationships "*as the machinery of public health policy delivery*". Interestingly, the study findings illustrated possible instances where sharing skills, resources or experience would be mutually beneficial (for example see section 7.5.4). With no exceptions, participants had clear understandings of what collaboration meant and the possible barriers to effective inter-agency working. Figure 8.2 serves to highlight, rather simplistically, the potential for inter-agency working. By visualising collaboration as a complex adaptive system and supporting the delicate inter-relationships between organisations, the function of the whole could potentially be more effective than each of the individual agencies in isolation.

Shaw and associates (2006, p.85) describe the public health agenda as

> *a double edged sword – with greater scope and opportunity on the one hand, and an increasingly large agenda and insufficient workforce capacity on the other.*

Shaw's observation does well to parallel the thoughts of decision-makers on the process of collaboration. The rhetoric is commendable but the realities are often untenable at a local level. Further still, Shaw, Ashcroft and Pushey (2006) talk about the risk of 'partnership fatigue' in the delivery of public health, which affects the relationship determinants of commonality, parity, multiplexity, continuity and directness. Respondents did not articulate this fear explicitly but some of the issues raised about data sharing and collaborative thinking, including trust, time limitations, culture and organisational changes (see figure 7.4, section 7.7), are in accordance with such a response. The theme of organisational change was echoed in another case study which reported that high job mobility and a culture of sustained organisational change made it difficult to establish relationships to enable effective collaboration between the research and service sectors Elliott and Popay (2000).

Figure 8.2: The inter-relations between organisations involved directly or indirectly in public health practice.



Key:
DH Department of Health; EA Environment Agency; HPA Health Protection Agency North East; LA Local Authority; LSP Local Strategic Partnership; NERIP North East Regional Information Partnership; PCT Primary Care Trust; SHA Northumberland and Tyne and Wear Strategic Health Authority; SS Sure Start; UNN University of Northumbria at Newcastle

Dunn *et al.* (2001) considered the uptake of GIS in the health sector (academia and NHS organisations) and examined the knowledge, experience and expertise of public health professionals. They build on this to consider factors affecting uptake of GIS in the health service. The findings from this study are commensurable with Dunn's conclusions in that GIS applications are still not commonplace within health agencies whereas the use of GIS is more developed and widespread in local authorities. The study presented here goes beyond a narrow biomedical and service orientated definition of the public health community to consider practitioners in local authorities, utility agencies, government organisations and quangos independent from the NHS, as well as NHS practitioners and academics.

This thesis moves the debate forward by using a different method (semi-structured interviews) to unpick more complex issues in greater depth than the survey and workshop methods employed by Dunn and associates, which merely scratch the surface of the issue of GIS use in public health. In the interviews more probing questions were asked to determine how decision-makers perceive GIS technologies and how the public health community values maps as evidence. Issues relating to awareness of the advantages and shortcomings of using maps in decision-making were also addressed. By considering these questions in greater depth, the answers can contribute to Dunn and co-workers' investigation into uptake and whether resources should be set aside to promote the use of GIS too all practitioners or whether specialist expertise is required within agencies. In the latter case, the answer might be to enable and support access to GIS by sharing of skills between agencies and by working in partnership to address issues with an inherent spatial dimension. In this way, complex public health issues can be investigated using multi-faceted strategies, which draw on a pluralistic mindset.

8.5.2 Complexity and multi-disciplinary working

Massey *et al.* (2006) comment on the need to make personal viewpoints and individual ontological and epistemological perspectives explicit when working in a multi-disciplinary milieu. "Epistemological plurality" (Massey *et al.*, 2006, p.145) was valued as a key part of the research design and positivists and constructivists alike contributed to different stages of Massey's study.

Positivists were charged with determining the study objectives and managing the counting and quantification aspects whereas interpretivists/constructivists focussed on the qualitative element of the study. As Massey and colleagues highlight there is a need for all players to be engaged and committed in order to work together (and in this case to use GIS to the greatest effect).

Carey and Smith (2007) discuss the problem of a common language specifically in the context of multi-disciplinary health research. They report the occurrence of different dialects hidden within a supposedly common language and the use of shared terms which can be loaded with incongruent meanings. The "*impenetrable*" language of GIS adds a further layer of complexity as many everyday words have a specific meaning in the context of GIS (McDonnell and Kemp, 1995, p.iii). The issue of finding a truly open and accessible language percolated through many of the interviews. This problem is likely to be particularly acute within public health, which by its very nature is multi-disciplinary involving practitioners with different mindsets and values, from fields as diverse as management, anthropology, medicine and politics.

It is crucial that GIS applications do not rest in the hands of those with only half the skills. The interviews suggested that in cases where there was a disparity between data producer (GIS expert) and data interpreter (public health data expert) maps were more likely to be misinterpreted or used erroneously. To quote Robert Sutton (2000, p. 28):

> *Knowledge management systems work best when the people who generate the knowledge are the same people who store it, explain it to others and coach them as they try to implement it. These systems must be managed by the people who are implementing what is known, not those who understand information technology.*

The importance of co-terminosity between data producer and interpreter was demonstrated in section 7.5.6. A collaborative approach is therefore essential within an organisation and between agencies when:

(i) determining the datasets (the type of data and timeframes) for inclusion in the data displays;

(ii) producing GIS map overlays;

(iii) interpreting GIS outputs.

A continuum emerges for collaboration with decision-making relevant at each stage (see figure 8.3). The study findings suggest that an organisation is necessary to champion the challenge of collaboration and address the plethora

of barriers cited. Dunn (2007) suggests that geography could be well placed as a co-ordinating body to facilitate collaboration. Likewise, GIS could be a suitable common vehicle for information sharing.

Figure 8.3: The continuum for collaboration using GIS: decision-making is relevant at each stage

Data for display	Overlay analysis	Interpretation	Dissemination
Which datasets? What timeframe? Which boundaries?	Data combinations?	Epistemological lens? Experience, values, beliefs?	To whom? Via what medium?

Whether or not the familiar rhetoric of multi-disciplinary practice has the potential to become reality is hotly debated. In order to give the initiative a chance of success, a sound understanding of the benefits of partnership working is necessary amongst the public health workforce. In the context of education spaces for public health, Williamson (2004) argues that a marked dichotomy is emerging in the Masters of Public Health courses available in the UK: one relies on sound but narrow epidemiological principles while the other embraces a broader ranging social model of health. Similarly, in this study, there were observable differences between how decision-makers from different camps perceived GIS and how they valued maps as evidence. Those with clinical training and also those working in the environment sector associated GIS with positivist approaches, the examination of causality and the reduction of problems into individual testable components. Whilst decision-makers working in the non-clinical health domain tended to be more interested in context, social and economic linkages and the possibilities of GIS for communicating information.

Perhaps a more useful conceptualisation of GIS would be as a tool that crosses boundaries and enables a multiplicity of functions including statistical analysis of cause and effect but also the capacity to integrate a range of data to present an issue from different perspectives and to communicate these data to diverse audiences. In parallel with complexity discourse, GIS has the potential to draw attention to subtle inter-relationships between seemingly disparate elements and therefore has the power to draw together different communities within public health, each with contrasting epistemological approaches, to further understanding and knowledge. With reference to the UK Masters of Public Health courses there may be a role for GIS to be taught as a compulsory

component in order to equip public health practitioners with the necessary skills and theoretical understanding to use GIS software and to interpret GIS outputs.

Carey and Smith (2007, online journal) suggest that the role of the public health researcher is as a "*jack of all trades and master of none*". To satisfy the demands of interdisciplinary working they propose the role of "*interlocker*" to provide depth of understanding across fields rather than a myopic focus on one specific area. They define the role of interlocker as:

> *taking part in a shared conversation, interdisciplinary health researchers pull multiple perspectives together and negotiate the tensions and divides of working between disciplines* (Carey and Smith, 2007, online journal).

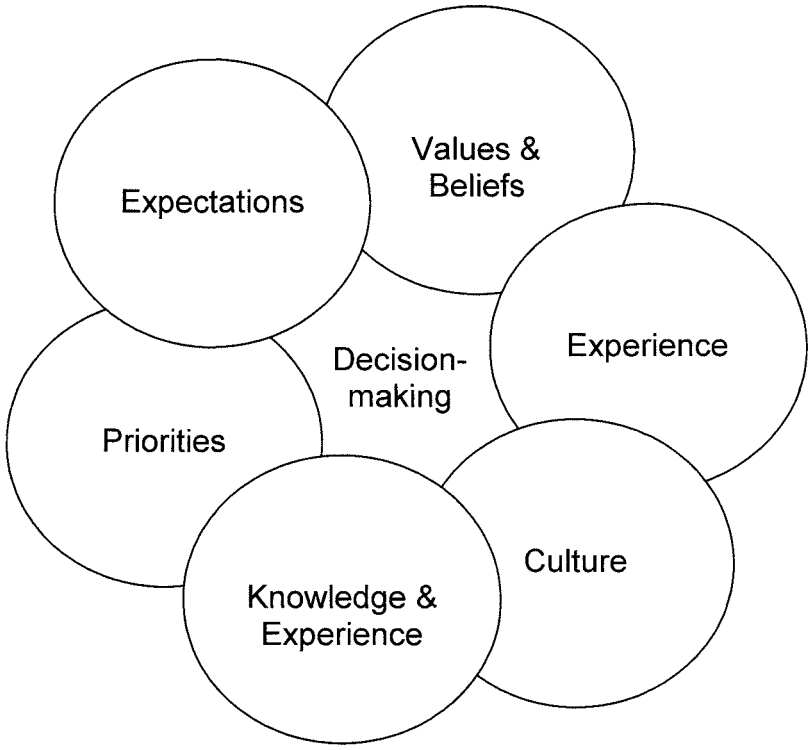
In this study, GIS has been used as an interlocker to draw together heterogeneous data in map format, which could then be used to transcend physical or philosophical boundaries between the various camps involved in public health decision-making. This perspective is commensurate with complexity thinking in that understanding of the inter-relationships between elements (or the bridges between disciplines) is valued more than in depth knowledge of the elements themselves. The central advantage of working at the interface between disciplines is the synthesis of new ideas and the translation of concepts common to one field into a new domain to stimulate insight, novel function or advanced critical debate.

8.6 Change management and complexity

Attention should also be given to how change can be achieved within organisations with respect to GIS uptake. The literature around change management might be pertinent to examine this area. Organisations tend to be power centralised bodies operating under conditions of strict departmentalisation, ingrained cultural norms and rigid hierarchical frameworks (Weir, 2007). Richard Seel endorses a complexity approach to change, within an organisational setting that aims to support stakeholders in the process of trying to find and build on common ground to move forward (Seel, 2000). Seel draws on a model of culture proposed by Johnson (1992), which describes the components of culture in a web or flower diagram where each of the circles or petals represents a single component. Such a model could be used to demonstrate the components of decision-making processes. Interestingly similar diagrams have been used throughout the thesis but have not been referred to specifically as a flower diagram (see figures 3.1, 6.1 and 8.2).

As Seel (2000) explains, the model is useful from a complexity stance as it demonstrates how change can only be achieved by thinking of the flower or web as a whole instead of each circle or petal individually. Similarly, attempts to change public health decision-making to embrace GIS techniques would require changes to the system rather than simplistic changes to each of the individual elements involved (see figure 8.4 below). To facilitate the incorporation of GIS techniques into public health decision-making, the system as a whole should be considered along with the connectedness between elements rather than simply concentrating on the specific elements themselves.

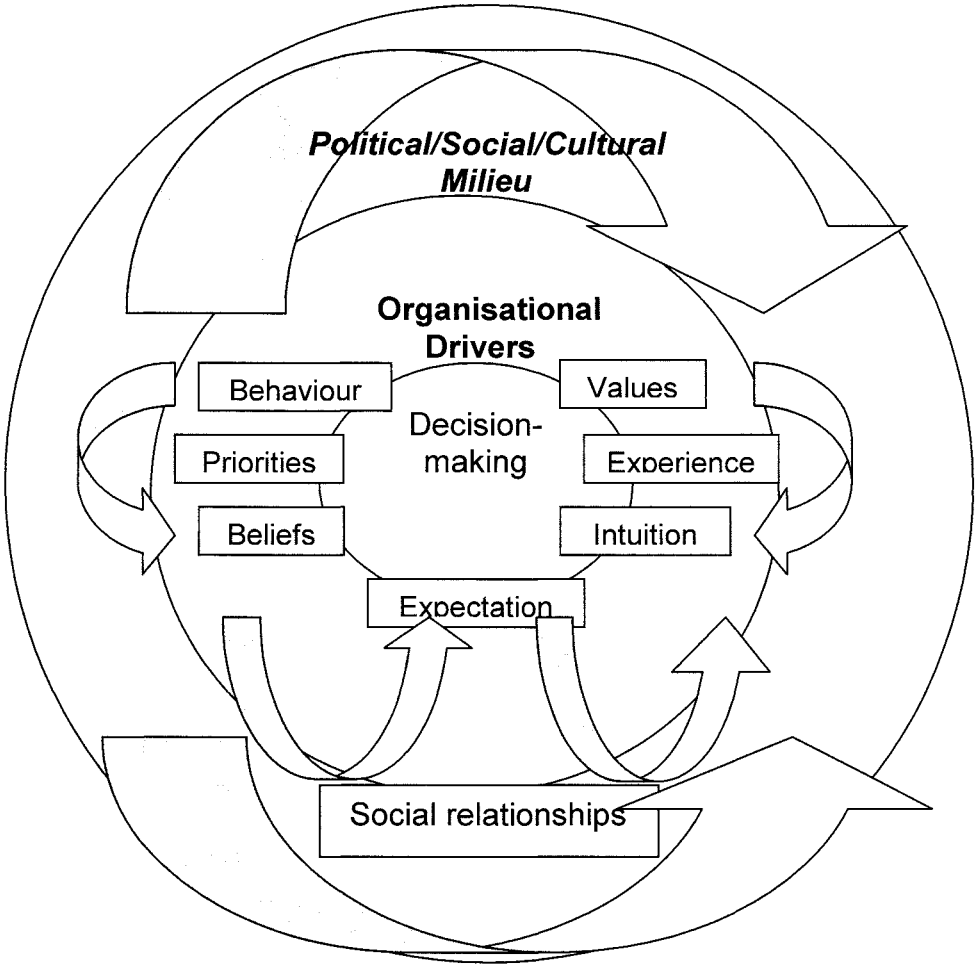
Figure 8.4: Decision-making pathways should consider the connections between active components rather than framing those elements as static and discrete (idea adapted from Johnson, 1992; cited in Seel, 2000).



It is appropriate now to reflect on the complexity model of public health decision-making proposed in chapter 3. Focussing on the relationships and inter-connectedness between actors in the organisations, rather than concentrating on specific drivers or constraints, change may be facilitated more readily, thus promoting effective sharing of knowledge, experience and expertise to bring about sustainable change. Following the complexity approach, the organisational culture, history and ethos should be taken into account as well as the outside political and social milieu. Complexity theory

recognises that it is not possible to plan, predict and control for every particular eventuality and encourages adaptability.

Figure 8.5: Pathways between variables in decision-making derived from this study



Stanwell-Smith (2001) argues that change is a natural force and there is a need, within the public health community to recognise, accept, define and best implement it rather than expending energy on futile attempts to circumvent natural and progressive change. Kelly *et al.* (2004) cited the capacity building framework for health improvement developed in Australia (NSW Health, 2001) as a template for enabling organisational change. To facilitate such a large-scale approach, organisational change at central, regional and local levels is necessary.

8.7 Complex methodologies in a complex research milieu

Dorling (1990, online thesis) argues that many methods endorsed by the social sciences are rooted to "*the times and places in which they were created, and can*

never be universally appropriate". This case study was complex, with a number of different but related elements. The GIS mapping exercise provided stimulus material to promote debate but the extent to which participants would engage with the report and acknowledge what it was trying to do was incalculable before the qualitative element of the case. That is not to say that the elements were orchestrated to take place consecutively. Rather the elements were interrelated and contingent, feeding into one another in line with the complexity approach.

Nutbeam (1998) describes the quest to find the best, one size fits all method within the sphere of health as ultimately futile in that any solution would be overly simplistic. In a complex world a battery of multiple and disparate methods delivered by a cadre of multi-disciplinary professionals is required to make sense of complex and resilient public health issues. Raphael (2000, p. 358) insists that traditional epidemiological or biomedical approaches fail to appreciate and make no attempt to uncover the "*complex patterns of interactions and situations*" that individuals and communities face. In contrast qualitative, methods are sensitive to unexpected emergent events (Raphael, 2000) in keeping with complexity thinking.

Similarly, Hammersley (2000) maintains that qualitative approaches have much to offer in working towards a better understanding of the policy process:

> *Qualitative research shows how people set up fronts in order to protect themselves from the unwelcome attentions of superiors or other authorities, that rules and policies always have to be interpreted if they are to be implemented, and that in the 'audit society' how they are implemented will increasingly be geared to giving the right impression, rather than doing the job in what is judged the best way possible* (Hammersley, 2000, p.401).

He goes on to assert that qualitative enquiry can examine and look for agreement or indeed disparity between policymakers assumptions and what the actors on the ground really think, believe and experience (Hammersley, 2000). This approach was fitting to examine and explore a new but potentially useful idea within public health decision-making and to access the experiential knowledge and wisdom of those working at the front line.

8.8 Childhood lead exposure: a complex public health issue

It is fitting now to return to the case example of childhood lead exposure. Due to the contentious and emotive nature of the issue of lead contamination

and its inextricable links with the inequality agenda, the interviews could have elicited strong feelings amongst participants. The mapping report was designed to be open to different interpretations of the maps in light of the differing backgrounds of study participants.

There seems to be a feeling amongst the public health community that the issue is just too difficult to deal with, remediation is likely to be expensive and it might cause hysteria so the government, so far, have chosen to ignore it. At present the government endorse a strategy that deals with contaminated land problems on an individual basis. Due to the ubiquitous and insidious nature of lead pollution there is a need to go beyond individual cases to promote bigger structural change. From a health inequalities perspective, the people most at risk from the effects of lead exposure do not have the same choices available as their lives are already blighted by an array of inter-connected ill health determinants.

In terms of decision-making the question arises as to when is evidence sufficient for action in terms of lead contamination? Brownson and associates state that the

> *demarcation between action and inaction is seldom distinct and requires careful consideration of scientific evidence as well as an assessment of values, preferences, costs and benefits of various options* (Brownson *et al.*, 2003, p.40).

The issue is complex and no gold standard evidence exists in terms of lead contamination and population exposure. There is evidence to demonstrate lead contamination but questions around the bioavailability of lead are not so straightforward (Vizard and Pless-Mulloli, 2003). Pathways between cause and effect are notoriously difficult to establish and health effects can be oversimplified and evidence misinterpreted or used erroneously.

8.9 Conclusion

The study findings have shown that maps are a powerful vehicle for communication but in reality they are in no way a panacea for practice. The corollary was highlighted that maps can be misused or misrepresented either wittingly or unwittingly, explicitly or implicitly or in transparent or concealed ways. Framed through the complexity window, the boundaries of public health issues are fluid, dynamic and ever changing. This way of knowing is commensurate with contemporary public health practice and accordingly

approaches to decision-making. Through undertaking the study and disseminating findings it is hoped that awareness of the potential of GIS mapping is raised with the aim of increasing uptake.

Sarantakos (1998) draws attention to the complexity of the real world, which cannot easily be reduced to facilitate measurement and quantification using experimental methods. Complexity theory acknowledges the disorder of real world phenomena and provides methods that are adaptive and fit for purpose (Stacey, 2007). The approach adopted in this study has attempted to bring together a multitude of disparate voices in an attempt to find common ground and understanding on multi-faceted and socially embedded problems.

Tsouros and Farrington (1999, p.275) acknowledge that there is a wealth of instrumental, interactive and technical knowledge relating to public health issues but "*there is a lack of effective communication of scientific evidence to decision-makers and a lack of adequate political commitment to promoting healthy public policy*". There are possibilities for GIS to be used to address this deficit, which will be discussed in the final chapter.

"*The important thing in science is not so much to obtain new facts as to discover new ways of thinking about them*"

(Sir William Bragg).

Chapter 9: Conclusion

9.1 Introduction

The conclusion seeks to demonstrate how well the study addresses the aims and objectives as well as illustrating how the findings can potentially influence public health practice and contribute to the contemporary knowledge base. The potential of complexity theory to facilitate understanding of public health decision-making pathways is reiterated. Participants supported the capacity of GIS to integrate multiple disparate datasets, which are not usually seen in combination, to foster understanding and to explore possible new patterns. The role for GIS, as an additional tool to the public health practitioner in data presentation, evidence production or data analysis purposes is emphasised. The chapter begins with critical reflection on how complexity can contribute to understanding and progress in terms of public health policy and practice. Decision-makers from health, environment and community spheres perceived the value of GIS and the status of maps, as evidence, differently. These differences tended to be steeped in patterns of understanding about the world.

GIS mapping has the potential to be used as a tool to promote community empowerment and bottom up approaches to public health issues. By considering the intricate and often underlying relations between components, GIS approaches can provide new ways of structuring decision-making pathways, which fall in line with complexity thinking. The chapter closes with debate around the limitations of the study, ways forward and suggestions for further work. Following the conclusion, the epilogue presents a reflexive discussion of the research experience. To avoid obscuring the debate this section will be written in the first person.

9.2 Complexity as a model for public health decision-making

In the real world, the settings in which public health decisions take place are seldom static and attempts to control for dynamic and contingent variables are untenable. Complexity, therefore, presents a fitting model of interpretation. In this era of evidence-based thinking, there is an explicit need to legitimise the role of GIS as more than simply a descriptive tool in decision-making. The power of GIS is ultimately its plasticity. Complexity theory provides an

appropriate framework to develop flexibility and adaptability. As Byrne (1998) maintains, it is not helpful to attempt to force order and linearity onto a world that is messy and fuzzy - which the public health domain undoubtedly is. Complexity discourse is flexible and fluid and can transcend boundaries in keeping with the ethos of public health.

Complexity theory provides a framework for those quick to dismiss GIS because it does not fit with their world-view or expectations. Decision-makers looking to employ GIS within a positivist, experimental model might believe that if GIS cannot prove causality it is not worthwhile. By the same token they might see no value in examining a phenomenon from a different perspective and in the use of GIS synergistically with other tools. This view does not fit with contemporary practice as public health is about processes just as much as it is about outcomes.

Complexity thinking emphasises the importance of examining how things are related rather than simply assessing and attributing cause and effect pathways. GIS fits into this strategy of exploring inter-relationships (rather than component parts), studying pathways between sub-systems and accepting elements of confusion and paradox (see figure 9.2). Although GIS emerged from positivist ways of knowing involving quantification, reducing the whole to its mechanistic parts and assessing causation (Harley, 1989), there is a growing recognition that GIS can go beyond this narrow world-view to be used as a tool within other paradigms such as complexity. There is potential for GIS to be used in an exploratory capacity to draw together various strands of data, not usually visualised together, which may lead to new insights and understanding.

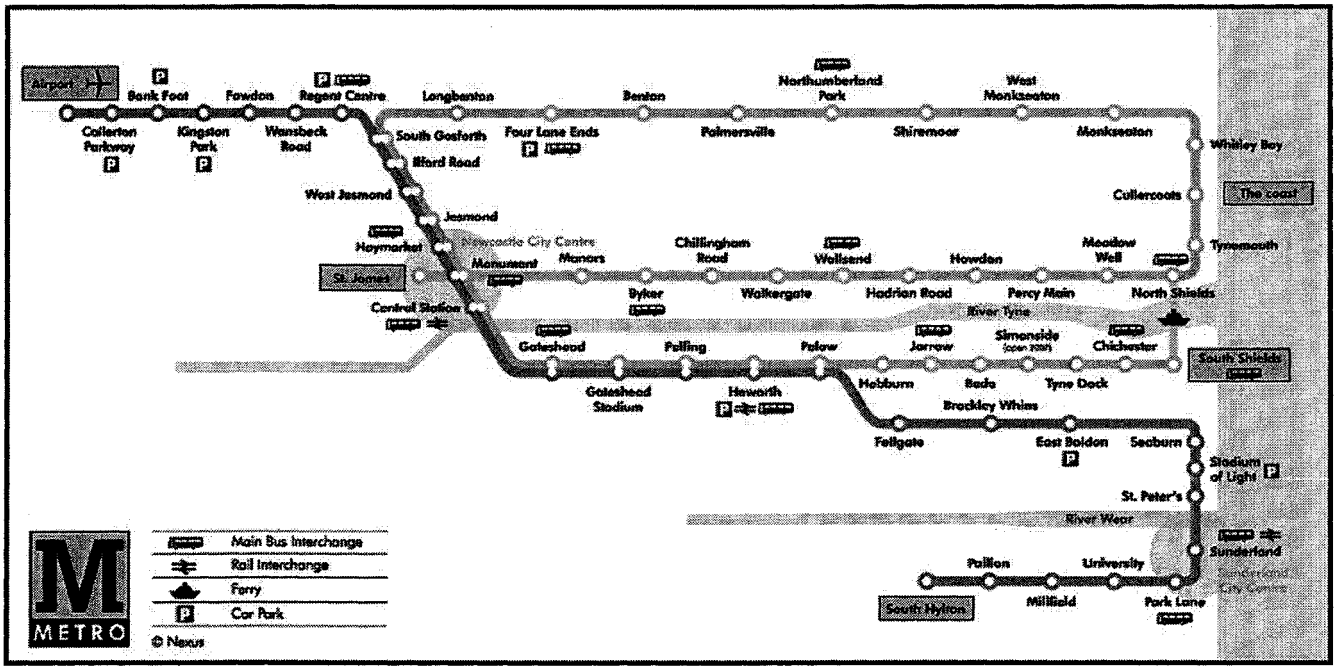
9.3 Maps as social constructions

The thesis highlights the potential of maps to be used as evidence in decision-making, based upon the way in which individuals relate to maps as everyday objects. Maps are ubiquitous in society: they are used for navigation purposes to get from A to B, on transport systems and as a means of interpreting Global Positioning Systems (GPS) information. They feature in news bulletins, newspapers and in weather forecasting. They are familiar and for that reason people are comfortable with maps. The question to consider, however, is whether or not maps are really neutral and for that matter are they

trustworthy? At some level even the most useful map tells lies (Monmonier, 1996).

Drawing on Monmonier's use of the London Underground map, an example is Newcastle's Tyne and Wear Metro map (see figure 9.1). This representation of the Metro system provides a highly user-friendly navigational tool, but the map is not an accurate representation of reality in several key ways. First, there is no indicator of scale, it appears to the reader that Haymarket station is equidistant from Monument and Jesmond but on the ground the distances are far more variable. Second, the use of north, south, east and west is only loosely accurate in that Wallsend is not directly east of Walkergate. The purpose of the map is to show you a way round on the Metro system and not to be geographically accurate. These fallacies are necessary to make the map useable, fit for purpose and not overly complicated. It should be remembered, however that the same 'lies' might be used to modify or manipulate GIS outputs to make them easier to relate to or more straightforward.

Figure 9.1 Newcastle's Tyne and Wear Metro

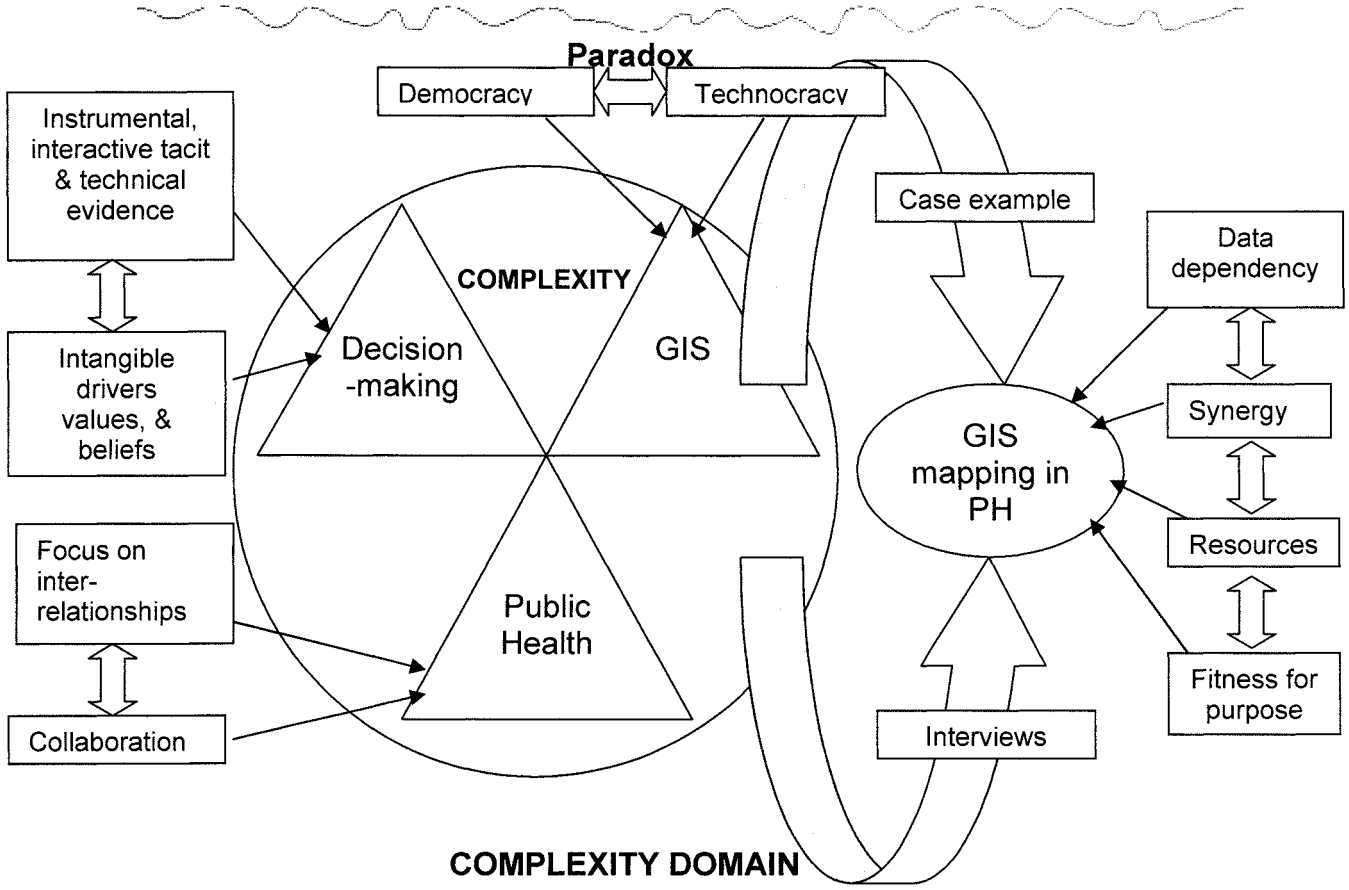


Source: http://www.nexus.org.uk/wps/wcm/connect/Nexus/Metro/Metro+map/

While maps are an efficient way of conveying information in an accessible format, there is a clearly a need for the reader to investigate the accuracy of the data displayed and to establish the purpose of the map. This

may entail the reader requesting metadata regarding the spatial information. GIS, as a technocratic device adds a further layer of complexity to the issue. There is a concern that because GIS is perceived to be a technocratic, map-making tool that GIS outputs are somehow safe and neutral. This misunderstanding could be problematic and was picked up on by respondents in the study who were familiar with the 'garbage in, garbage out' adage. For those with less experience of data management issues or for a lay audience the issue may not be so explicit and the trustworthiness of technical GIS outputs may not be called into question.

Figure 9.2: Returning to the boundaries of the thesis: lessons learned



9.4 Implications for public health evidence-based policy and practice

Accounts from participants regarding the value of GIS in decision-making were rooted in their own personal realities. Similarly, the findings relating to the use of maps as evidence are in agreement with Raphael's (2000, p.361) proposition that "*ideology, values and principles influence what is accepted as valid evidence*". The epistemological assumptions were affected by the individuals'

world-views, which in turn were shaped by language, gender, class, age and experience.

Common themes uncovered in the interviews were grouped according to the ontological, power, functionality and collaboration discourse typology. The observed differences between individuals correlated with those noted at the organisational level, that is, differences were likely to be a function of organisations working under disparate paradigms reinforced by individuals each having their own belief system and ways of knowing. To qualify this explanation with an example, it was noted that decision-makers with a clinical background tended to perceive GIS as part of the positivist programme and were keen to assign a role to GIS in analysis and deduction of cause and effect pathways. Although the aim of the study was not to label or compartmentalise people into groups based on prejudgements, differences were plainly evident between NHS associated organisations (and service providers) compared with community practitioners.

The paternalistic model of decision-making, often favoured by clinicians, enables those with the power base to decide what to tell and what not to tell with respect to information and intelligence. Decisions are often biased as knowledge and accordingly power is the preserve of a small group of elite. This model is in direct competition with the fundamentals of complexity, where the idea of not taking action just because a problem is too complicated is refuted. Conversely, public health practitioners embrace the bottom-up community model of decision-making and there may be a role for GIS and universally accessible maps within this paradigm. As Plesk and Greenhalgh (2001, p.626) recognise "*tension and paradox are natural phenomenon not necessarily to be resolved*". Thus the differences observed between participants and organisations in the study should be understood and made explicit but not necessarily reconciled.

A key construct amongst decision-makers was the notion of practicalities such as provision of resources and avoiding duplication of work. Several respondents were keen to highlight the potential of GIS beyond merely data visualisation and advocated the use of GIS for analytical purposes. Many acknowledged that there was potential for GIS to be used further within their organisation. The factors cited as limiting GIS uptake were not surprising. These included concerns and tensions around time and resource constraints, training, intra-organisational politics and, probably most significantly, a culture of

organisational change with an emphasis on targets resulting in an environment of insecurity and fear.

By focussing solely on targets policy makers can lose sight of the broader picture and the interconnectedness of health determinants (Gabbay, 1998). The study has demonstrated that, within public health, maps can provide a new perspective to old problems that often have an obvious spatial dimension. GIS map representations have the potential to illuminate inter-relationships and to highlight previously unrecognised pathways. This potential resonates strongly with the complexity agenda where the focus is on the relationships between components rather than the components themselves.

Overall GIS was perceived as a tool for decision-making, not a simple solution that could transform public health policy and practice. Maps were thought to be powerful for communication purposes if used with caution. By applying GIS as a synergistic tool it can be used to inform the complete picture to understand the totality of an issue. In the information era, Weir recognises that

> *the enhanced capabilities of information processing, data storage and management systems and electronic data-transmission have opened up radically improved possibilities of communication for enterprises and individuals* (Weir, 2007, p.4).

GIS can be viewed as a tool to facilitate the transition of data into information for communication purposes. The use of maps in data presentation can personalise the issue of concern to make it seem more tangible and real. In this way maps can be used to trigger action and to 'humanise' unreachable problems in an effort to make them manageable.

In terms of models of evidence-based decision-making, the public health community cannot wait for scientific certainty and clear consensus, before taking action and making decisions for policy and practice. Brownson (2003) cites the example of the emergence of HIV, where clinicians and policy makers could not ignore the problem just because the pathogenesis of the disease was unknown. For this reason, GIS representations should not be dismissed because they do not provide immediate answers (and in many instances produce more questions). There is a need to respond and take action in a climate of uncertainty and risk, and models of complexity can provide a suitable approach.

9.5 Study limitations

The study reports views and opinions in relation to the value of GIS mapping rather than presenting direct evidence of how GIS and map outputs are used in practice (Petticrew *et al.*, 2004). Despite initially targeting a sample of eight, sampling snowballed and twenty-three interviewees were eventually recruited to the study. The sample size was designed for a qualitative approach, therefore the findings cannot be widely generalised to other public health decision-making processes. Likewise, it is not possible to make realistic comparisons across disciplines and with different geographical localities. Taken as thematic issues there may, however, be some transferability to other public health 'patches' with similar demographics and socio-economic profiles. Broad generalisation of the findings from the study is difficult due to the very fact that public health problems are multi-factorial and context embedded. Different factors are at work within different populations and in different locations (Speller, Learmonth and Harrison, 1997).

More time could have been spent conducting fieldwork including participant observation; much of the time allocated to data collection was consumed with undertaking preliminary explorations of the GIS toolbox. This could have enabled triangulation of findings through different methods or using different sources. Time limitations precluded member checking of the transcripts. Instead, the findings were discussed with a range of people within academia, at a regional conference and at a University seminar to validate thematic interpretation (Berendson *et al.*, 2007). Participants were sent a copy of the presentation abstract as well as a report of the study findings.

The study does not include dialogue with local communities, which represents a key part of contemporary public health rhetoric. The case example, childhood lead exposure, is a highly contentious issue which if communicated to the public could be sensationalised by the media, creating panic and adding to the sense of fear and risk already present within disadvantaged communities. Such communication with appropriate management and response was beyond the scope of this study. Further work could involve consultation with the public regarding the role of GIS in the health domain.

One of the main strengths of GIS is the capacity to undertake sophisticated geo-statistical analyses. No spatial analysis was undertaken in

the study as it was felt to be inappropriate. The data were critiqued in depth and deemed not to be robust enough for statistical analysis, in terms of consistency, completeness, relevance, reliability and validity. Moreover, given the inaccessibility and specialisation of geo-statistics such analyses may have been beyond the grasp of even the most numerate participants.

Materia and Baglio (2005) warn against the potential for complexity theory to be manipulated and used to justify economic or power related ends. Indeed, there is a danger that the complexity approach could disappear into a relativist's vacuum where uncertainty regarding background, frame of reference and context of a public health issue might render the theoretical approach impotent. Complexity could also be accused of enabling an excuse to 'over-think' a problem to purposely avoid taking practical action. Critics of complexity discourse question whether researchers fall back on complexity just because an issue is challenging and there is no other way forward. For example, by concentrating on the contingent relations between aspects of public health policy around childhood lead exposure, decision-makers may be so fearful of the possible acute and distal effects that they may avoid making any decisions altogether. Another difficulty associated with the complexity approach is the absence of robust frameworks with which to conduct empirical research (Cooper and Geyer, 2007)

Equally, complexity theorists could be criticised for vagueness and ambivalence in relation to theory development. Such criticism is unfounded as complexity attempts to forge a way forward against modernist orthodoxy in the midst of tension, chaos and constraints. Genuine acknowledgment and acceptance of the textured and non-homogenous nature of a problem, in terms of elements of order and disorder, is required to make progress on historically and culturally embedded problems. There is no clear single strategy to deal with complex and multi-layered public health problems. In this instance, complexity theory was employed because it was felt to be the most fitting and instructive approach with which to examine public health decision-making processes.

9.6 Ways forward

The research approach employed in this study does not permit recommendations to be made from the study findings. In line with complexity

theory it is more fitting to suggest lessons learnt or themes with which to take theory and practice forward. In terms of GIS in public health decision-making, there is an explicit need to be pragmatic. There are no all-encompassing recommendations. For example, one agency's lack of resources was an obvious constraint whereas for others there were deficits in terms of trained personnel to operate GIS and to interpret mapping outputs.

Complexity dialogue is fundamentally against the idea "*that order needs to be created by external forces*" (Kernick, 2006, p.389). Thus, rather than attempting to enforce the use of GIS technology within an organisation, a supportive environment should be created (equipped with sufficient resources in terms of time, technology and skills) through which the use of GIS can emerge.

The notion of using GIS to facilitate data sharing and collaborative working was accepted positively but the need for a key organisation to champion the initiative was also highlighted. Community partnerships already have good relations with bodies in the public, private and voluntary sectors but they may lack the 'political clout' to motivate partner agencies. The Public Health Observatory (PHO) may be an appropriate leader especially since PHOs have been targeted as the key bodies to progress central government's initiative to strengthen the intelligence base for public health (Raine, Godden and Mckee, 2006). Their role regarding GIS could be to strengthen existing partnerships and develop new relationships between agencies involved directly but also those involved indirectly, in public health practice.

Kelly, Speller and Meyrick (2004) suggest that consideration should be given to the interface between the methods, methodologies, frames of reference and underlying epistemological assumptions that contribute to the evidence base. Along these lines it follows that those interpreting GIS evidence should have a sound understanding of the principles of GIS science. This leads to a key issue raised by the study findings of the disparity between the data producer and data user.

Again the issue of whether to employ a GIS specialist or to make GIS accessible and available to all within an organisation is context dependent and not at all clear-cut. In some instances - especially when GIS is to be used for geo-statistical modelling and sophisticated forms of analysis such as krigging - it may be more fitting to employ a specialised GIS consultant rather than investing in making GIS part of the universal desktop facilities. This specialist should be

trained in all aspects of the GIS toolbox especially modelling and should work on GIS full time so as to maintain the skill base. It is important that he or she should also be trained in public health so that they can contextualise and interpret the data as well as analyse it. This is crucial because of the many opportunities for misuse of GIS outputs, either wittingly or un-wittingly due to a lack of understanding of the public health milieu. Given such a situation the most useful GIS functions could then be explored to their full potential rather than just scratching the surface of GIS techniques and confining use to cartographic purposes only.

In other instances where GIS might only be used for data integration and communication purposes (as in the mapping exercise of this study, see chapter 6), it might be more appropriate for all members of the team to have access to GIS software. It is essential, however, that each individual is given relevant and comprehensive training in GIS theory and practice with the caveat of the potential for misunderstandings and misuse of maps fully explained.

The science behind GIS is pivotal in producing meaningful maps. There is a common misconception that GIS is simply a number crunching exercise. It is, therefore, critical that GIS users are aware of the key concepts underpinning map-making such as the need for metadata[14], denominator data, and high quality attribute data. GIS does not fit into one research domain; it is not a methodology as such, rather it should be used as a method or a tool. Those wishing to use GIS should be made aware of the distinction between mapping and GIS science, which was recognised by respondents more familiar with GIS approaches, particularly those who had used the software in the past. If the study was to make a recommendation, it would be to be explicit about the difference between cartographic GIS mapping and GIS mapping for analytic purposes.

Participants were concerned about the aim of GIS and the idea of using GIS only in the right circumstances was a recurrent theme ("*you can't let the tail wag the dog*" [Section 7.5.2, transcript V, 8/359]). GIS should be viewed not only as a tool, but one with a diverse range of facilities. By affording plurality to public health strategies in terms of setting the agenda for research and determining the direction for best practice, the most relevant and fitting method can be

[14] Data about the data used to contextualise the map outputs.

chosen to address the topic of interest. As Beaglehole and associates recognise

> *many disciplines are needed...to provide the evidence base for health policy making by use of appropriate methods to answer appropriate questions to inform policy* (Beaglehole *et al.*, 2004, p.2085).

The study illuminated the inextricable relation between public health and politics. Political tensions cannot and should not be ignored when considering GIS usage. Several issues should be taken into account. First, the issues of ethics and disclosure are paramount. Concerns around identifiability and confidentiality with respect to GIS maps should be recognised and made explicit in the ethics protocols for Local Ethics Review Boards and Research and Development boards of Primary Care Organisations. The fallacy that maps are neutral and safe because the data are geocoded and somehow less identifiable must be exposed and the potential for identifiability fully explained.

Second, there is a need to avoid the deliberate use of closed and obfuscating dialogue and acronyms. A 'commonness' of language is needed to provide an 'equal playing field' and to reduce the tensions in the form of insecurity and territoriality often encountered in collaborative ventures. Likewise, this notion of a common and inclusive language should be reflected in the elements of the mapping process. For example, phrases such as 'choropleth map' (the shading of an area in proportion to a measurement or variable) might immediately cause stakeholders to disengage with the process. Similarly, the word 'krigging' (the interpolation of a series of points to produce a mapped surface based on the average of like neighbours) is confusing even to those familiar with GIS. Referring to the choropleth diagram simply as 'a map' and krigging as 'the process of modelling a surface' might be the answer.

In summary, there is an overt requirement to be open and transparent especially in collaborative working, to make assumptions explicit and to look for consensus in definitions and meanings. Such issues represent challenges for policy and practice. Workshops could be employed to develop good interagency relationships and a shared working ethos.

9.7 Further Research

The study has examined real world issues in the context of public health: the key study themes of communication, collaboration, technology and

complexity are central to modern public health debate and practice. The mapping report was produced to illustrate the limitations as well as the benefits of maps as evidence. A lack of time and expertise precluded the development of a map system combining water, soil and industrial lead levels to produce a composite score of environmental lead exposure using GIS.

Maps are pictures which represent a snapshot of an issue. They have currency in a range of fields from history and art through to science. In this way they are accorded 'status' and validity. The maps produced in this study do not incorporate a temporal dimension, though GIS does have the capacity to illustrate how an issue might change over time. There is a wide array of possible public health applications for collaborative GIS approaches between agencies. Examples of potential applications could include: service provision with respect to those demographics where need and provision do not correlate; service uptake in relation to British Minority Ethnic groups; changes in birth weight over time and place; monitoring the spread of the obesity epidemic; historic and contemporary spatial patterning of local markets; changes in the patterning of public transport use.

Focus groups could also be conducted to examine how interacting with others can aid understanding of GIS maps in a multi-agency environment. Further research could provide opportunities to conduct follow up interviews to examine how attitudes and perceptions of GIS have changed over time. Complexity approaches to data analysis favour techniques to study the emergence of change over time (Byrne, 1997). Future studies might involve a return to the original interviewees to discuss how their understanding of GIS and their relationships with maps for decision-making have changed or evolved.

The study was presented at a local research and development conference and at a university public health network conference as a method for validating the study findings (refer to section 5.7.2 and Appendix XI). Open dialogue with participants confirmed that the low uptake of GIS was likely to be due to issues around resources and training but also to fear of change, territoriality and insecurity within the turbulent NHS environment at present. One participant suggested that, to enhance the use of GIS mapping in public health, the basic principles of GIS could be introduced in schools at primary or secondary level. The study findings have illuminated how people relate to and engage with maps; it makes sense that GIS could be used as an education aid.

Clearly, the costs associated with GIS packages might prove to be a limiting factor but the power of maps to communicate in a comprehensible and evocative fashion is one that could be harnessed in innovative projects.

9.8 Concluding Remarks

There is a paucity of studies on the value of GIS in the field of public health; the study presented here has attempted to fill this apparent gap. As far as is known, this is the first study to use a qualitative and inductive methodology to explore how public health decision-makers value GIS as tools, and maps as evidence in decision-making processes. The qualitative approach fits well with the types of questions addressed through the research. Although the study did not set out to test *a priori* hypotheses the design of the data collection and analysis strategies was guided by questions around how decision-makers value GIS technologies and maps as evidence. Personal experience with GIS mapping and concerns about data misrepresentation and erroneous use of GIS uncovered areas for exploration in the interviews. The interviews also examined the concept of using GIS as a vehicle to promote interagency collaboration, a core notion in contemporary public health policy.

According to Fraser and Greenhalgh (2001, p.801) "*the complex real world is made up of messy, fuzzy, unique and context embedded problems*". Public health is a minefield of multi-faceted and non-monocrome problems. To negotiate this landscape the public health practitioner should be equipped with a non-linear mindset. The issues of public health are at one level simple (evidence that lead is toxic and is present in the environment); at another the realities are highly convoluted and difficult to disentangle (methods of remediation when wide areas of the UK land mass could be defined as contaminated with lead; reducing inequalities in terms of lead exposure). Building on complexity theory's focus on relationships, in contrast to individualistic approaches favoured in the past (Pearce, 1996), GIS has served to highlight linkages, relationships and inter-connections between aspects of childhood lead exposure. GIS is well placed to draw attention to the importance of place when considering any public health problem or intervention (Krieger, 2003) and the use of complexity theory enables the intricate dynamic between time, person and place to be made explicit.

The study has also served to highlight a caveat associated with GIS mapping, one which applies to most forms of data representation; the potential of GIS, and maps as evidence, to be misinterpreted or misused. Maps use a complex language, they immediately communicate a message and often evoke an emotive response, but the meaning of the message differs between individuals depending on their assumptions, beliefs and value systems. However the capacity of maps to invite multiple interpretations is not necessarily negative and can be exploited to broaden debate.

The study has employed an eclectic methodology within a case study design, to explore the capacity of drawing together multiple disparate sources of data using GIS. The study findings have captured multiple views regarding the value of GIS in a decision-making scenario and have drawn on complexity theory to unpack the various issues and obstacles concerning the use of maps as evidence. Progress can be made by accepting the tensions and divisions relating to decision-makers' value systems, rather than attempting to reconcile differences and impose an over-simplified, generic model of decision-making. Pluralistic approaches to evidence are required. This observation is not wholly new, having been asserted in the Leeds Declaration of 1995 (Naidoo and Orme, 1998).

Evidence should not be based on simplistic mono-technic studies designed to yield rapid but often unsustainable, results. Such studies control for confounding factors (Speller, Learmonth and Harrison, 1997) which serves to reduce the complexity of the issue; this may in turn detract from or skew the essence of the problem. Evidence-based approaches are not wholly wrong, rather the preconceptions and assumptions associated with evidence-based thinking need to be deconstructed and modified to take into account the complexities of real world issues. At the information level GIS can effectively integrate a range of datasets to share intelligence. However, the reality of bringing together multiple and disparate agencies, with differing cultures, priorities and ways of knowing, to work in partnership is far more complex. The lessons learnt through this study can be translated to other fields, thereby sharing skills, knowledge and experience to promote collaboration and integrated thinking across the public health landscape.

The study has demonstrated that GIS is a complex tool with the power to communicate effectively but also the capacity to misinform. The use of maps as

evidence can enable a common language with the caveat that maps are open to interpretation by different camps operating under multiple, disparate realities.

Epilogue: Reflexive thoughts

As Massey and co-workers (2006) observe, reflection on the process of the research is as important as interpretation of the results and outputs of the inquiry. The epilogue describes the researcher's learning experience and as such is written in the first person. The relationship between objectivity and subjectivity is complex. The researcher's voice and journey should have a place in the thesis; complexity helps to map out this story and to reconcile subjectivity and objectivity. Sharrock and Anderson (1991) argue that the use of the third person in positivist texts can sometimes lead to obfuscation rather than clarification. It has been suggested that writing in the third person can result in detachment as the author subconsciously hides behind the term 'the researcher' (Parker, 1999). The mapping exercise was demanding and unstraightforward, it was a learning curve for 'me'. It was not 'someone's' journey but 'my journey'. By recognising skills from both the positivist and interpretivist traditions, complexity theory has helped me to celebrate who I am and not to dampen down or mask my identity. It has been used in the thesis as a lens for clarification purposes and as a navigation device.

My experience of GIS aside from an introductory level MSc module was limited so the exercise was challenging and despite undertaking a module on GIS science (which was theoretically rather than practically focussed) my journey was self-taught in a 'learn by doing' fashion. When engaging with GIS myself, I had to revise my own opinions and assumptions about what GIS actually was. It was certainly more than a cartographic tool or a number-crunching device, and understanding of the key principles of GIS science was essential to produce meaningful maps. I am not an expert in GIS technologies and this seemed to be perceived as an advantage within the public health community during the interviews. I was not viewed as a threat as I understood the concerns and fears relating to the 'foreign' language of GIS.

As a public health researcher I have been trained in positivist ways of knowing but essentially I am a pluralist in terms of my methodological approach (the methodology and methods chosen should be suited to address the research question of interest). Initially, I had to unlearn some deep seated prejudgments associated with the biomedical paradigm (Newtonian logic, reducing complex issues to their component parts and the search for a single

truth) and realise that there is not just one way of knowing but several. In terms of the qualitative research component it was necessary to be fully aware of any source of bias that may skew the data interpretation process. It was, therefore, important to make my biases as a researcher explicit with the proviso that I could not remove the influence of personal values, opinions and assumptions from the research process entirely. With respect to the research process it was necessary to begin data analysis at an early stage so that data collected early in the process could feed into the later interviews. Again this approach contrasted with positivist studies where data collection and analysis occur sequentially.

Rather than viewing my academic background as 'baggage', in line with complexity thinking, I tried to reframe it as a resource (Parker, 1999). The journey articulated in this thesis is one of many possible journeys. Someone else looking at the same data and taking the same journey may have seen things differently and told a different story. For example, a geographer might be interested in developing a system to produce an aggregate spatial score for lead contamination which integrates soil, water and housing lead levels. Likewise an emancipative researcher could be interested in uncovering the stories behind the maps, the links between lead pollution and deprivation, social and environmental justice and accountability for elevated soil and water lead levels.

Insights from complexity discourse can also be used to understand the dynamics of the interview process. The interview scenario can be viewed as an adaptive system with fluid boundaries and complex dynamics where changes in the respondent's behaviour feed back to the interviewer and vice versa. The role of gender adds to this complexity. As a female researcher within a traditionally patriarchal world, engaging with decision-makers and establishing a relationship of trust, to enable an open and even dialogue was challenging (see Appendix IX, Excerpts from the Research Diary). One male respondent even tried to draw back control and power in the interview situation by questioning me about my interview technique and health status once the audio equipment was turned off. I felt this was somehow inappropriate but on reflection it perhaps underlined the need for certain senior managers to maintain control in different ways. Curiously, it may also demonstrate the compulsion of professionals with medical backgrounds to 'make a diagnosis' and reaffirm their professional status.

In contrast, the experience of interviewing the female participants was without exception, positive, non-intimidating and enjoyable. Finch (1984) suggests that the process of interviewing women is facilitated by shared identity and the success of the interview depends more so on that identification process rather than specific interview techniques or sociological research skills. The area of gender and elite interviewing is multi-faceted, convoluted and highly emotive and warrants further examination within the complexity domain.

This thesis has emerged from a complex journey involving elements of order and chaos, consensus and disagreement as well as paradox and simplicity. There are areas where the complexity paradigm has highlighted further dissonance and lack of clarification but the thesis has served to draw attention to these fuzzy areas in public health decision-making, rather than trying to mask or ignore them. The concept of emergence resonates particularly strongly as the work began as something quite quantitative, focussed on cause and effect and evolved into a study concerned with inter-relationships (between individuals, structures and agencies and within the data of interest). Initially the mapping and interview phases were seen as binary processes but what soon became clear was the importance of the bridge linking the two. The study's contribution to knowledge lies in this 'in-between space'.

Glossary

ArcMap	GIS Software part of the ArcGIS software package
Choropleth	a map where a gradient of colour is used to display changes in a variable
CLEA	Contaminated Land Exposure Assessment: s framework for the assessment of risks to human health from land contamination.
GIS	Geographical Information Systems: a system for collecting, collating, synthesising and displaying spatial data
Krigging	Geostatistical method of interpolation based on spatial variation of known points
Metadata	Information about the data to understand the relationship between data and context
Raster	Data stored in the form of a grid or pixels, the arrangement of the pixels determines the shape and location of the object in space
Vector	Data stored in the form of points, lines or polygons

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Appendix I: The Mapping Report

northumbria
UNIVERSITY

Mapping of environmental and population data regarding childhood lead exposure in Newcastle upon Tyne

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Abbreviations and Glossary of Terms

BME	Black and Minority Ethnic
CLEA	Contaminated Land Exposure Assessment: The CLEA model was released by the Department for Environment, Food and Rural Affairs and the Environment Agency in 2002. The soil guideline values for a number of soil contaminants derived from the CLEA model, act as indicators of unacceptable risk to the health of site users. Where contamination levels exceed these guideline values (Lead: 450mg/kg for residential land/allotments; 750mg/kg for commercial/industrial land) further investigation &/or remediation is required.
DWI	Drinking Water Inspectorate: The DWI regulates public water supplies in England and Wales.
EU	European Union
GIS	Geographical Information System: a computer based software package with the capacity to store, manage, manipulate, interrogate and analyse spatially referenced data.
IMD	Index of Multiple Deprivation 2004: IMD is a composite measure of deprivation at super output level for every local authority area in England. IMD is regarded, by both researchers and practitioners, as the most reliable indicator of inequality and is used to compare the difference in lived experience between people in different geographical areas. IMD is a single score based on seven domains. These domains, with their respective weighting, are as follows: Income Deprivation (22.5%); Employment Deprivation (22.5%); Health Deprivation and Disability (13.5%); Education, Skills and Training Deprivation (13.5%); Barriers to Housing and Services (9.3%); Crime (9.3%); Living Environment Deprivation (9.3%).
IPPC	Integrated Pollution Prevention and Control: the 1996 European Union IPPC directive set out regulations on permitting for industrial installations with the central aim of minimising pollution from point sources. Part A installations produce emissions to air and water and are regulated by the Environment Agency, whereas Part B installations emit only air pollutants and are regulated by Local Authorities. Part A2 installations produce both air and water pollutants but are regulated locally.
Pb	Chemical symbol for the heavy metal lead.
RMSO	Regional Maternity Survey Office
SAT	Standard Assessment Tasks or Standard Attainment Tests: SATs are taken by children at the ages of 7 (key stage 1), 11 (key stage 2) , 14 (key stage 3) to ascertain the level of the National Curriculum that they have reached.
SOA	Super Output Area: Lower layer super output areas (referred to in this report as SOAs) are part of a new census geography based upon aggregates of output areas (OAs). Output areas are the smallest grouping in the hierarchy and cover 100 to 150 households. In Newcastle there are 889 output areas divided into 173 super output areas with each SOA containing approximately 650 households and 1500 people
WHO	World Health Organisation

Purpose of the report

This report provides a summary selection of the GIS maps constructed from secondary data in Phase I of the PhD study. The objectives of the preliminary mapping phase were:

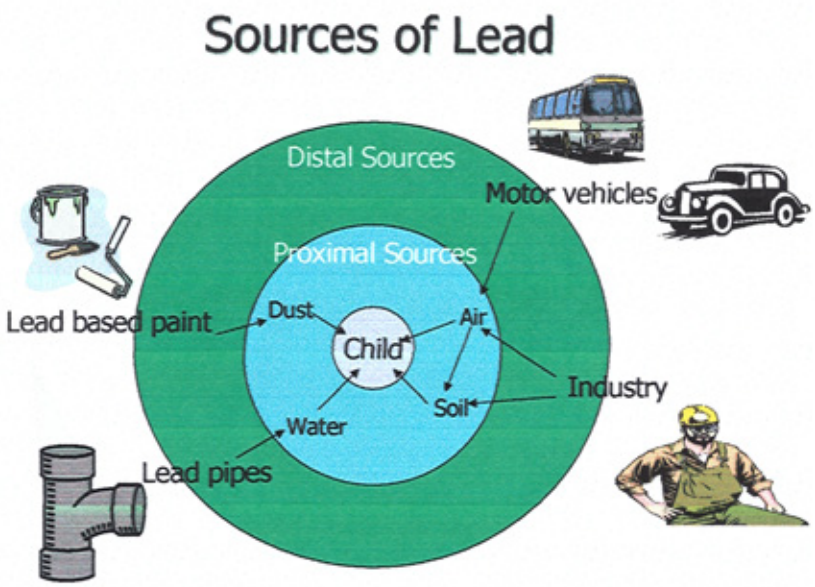
(i) to draw together the available data on lead contamination in the soils and waters of Newcastle upon Tyne;
(ii) to construct spatial maps and overlays from empirical data collected in tabular format;
(iii) to produce stimulus material using GIS for interview discussions in Phase II;
(iv) to inform the interview schedule for Phase II.

Phase II of the study aims to explore the value of GIS mapping tools in the evidence-base for decision-making practices. It should be emphasised here that these interviews will not be addressing accountability issues or opinion on current policy relating specifically to childhood lead exposure. Instead the issue is being used to demonstrate the use of GIS software for data integration and display and the possible applications of GIS in public health decision-making processes.

Historical and contemporary environmental data are presented, together with demographic information to explore possible inequality issues. Maps of environmental lead are also overlaid with data relating to child health and development. These data are relevant as lead has been shown to be causally linked to loss of intellectual development and educability in children and a correlation between lead exposure in mothers and low birth weight babies has been demonstrated in a number of studies. The maps are intended to provide descriptive data based on what evidence is available and in no way are they attempting to uncover causal relationships between environmental lead and adverse effects on child health and development. In summary, the context of decision-making is central to interview discussions and should be borne in mind when reviewing this document.

Introduction

This report uses the example of childhood lead exposure to demonstrate how a Geographical Information System (GIS) can be used to understand a re-emerging public health issue. The study explores the value of spatial mapping to visualize the multifaceted aspects of a complex child health problem, using pictures rather than a mass of statistical tables. The issue of childhood lead exposure has been absent from the public health agenda for the past two decades despite the current government's promises to tackle issues of inequality. Exposure to environmental lead contamination is likely to be a compounding pressure on children already suffering from the burden of social and economic deprivation. The study will examine the value of GIS mapping as an aid to making the best possible decisions relating to children's health and development.



Lead – the facts

◊ Lead has no known use in the human body.

◊ Current epidemiological evidence suggests that there is no safe level of endogenous body lead.

◊ Lead can be leached from old water pipes especially in areas with soft water where the pH is acidic. High temperatures also increase the leaching rate.

◊ Lead is a persistent heavy metal in soil. The legacy of Newcastle's industrial heritage, therefore, remains a problem with potential public health ramifications.

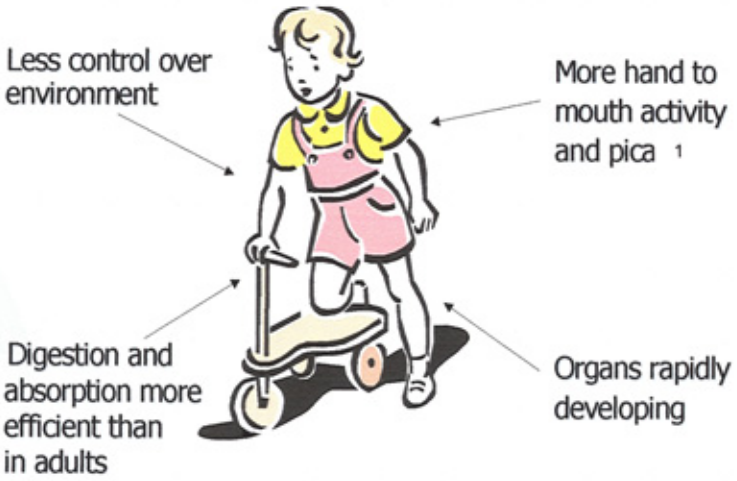
◊ Currently there is no routine screening of children for lead uptake and there is a lack of routine environmental surveillance for lead (with the exception of random water lead sampling for Northumbrian Water).

Lead is ubiquitous in the environment, being found in a range of sources, including soil, dust, air and water, as shown above. Since there is no routine surveillance of childhood blood lead levels in the UK, lead exposure is commonly employed as a proxy measure of lead uptake and will be used, here, in this study. Lead affects a number of target organ systems and in international studies, long term lead exposure in children has been causally associated with loss of intellectual development. In addition, lead is known to affect intrauterine growth, resulting in low birth weight

babies born to mothers exposed to lead during pregnancy. There is evidence to suggest that historical exposure to lead can also affect pregnancies in subsequent years. This is because lead stored in bone can be mobilized into the bloodstream making it possible for the teratogen to cross the placenta.

Children have no control over their immediate physical environment - unlike adults - and are at a heightened risk of exposure to lead for multiple reasons as shown in the diagram below.

Susceptibility of Children



1 Pica is defined as the ingestion of non-food items

What is GIS?

◊ GIS stands for geographical information system, which is a computer software mapping system that can collect, store, manage and manipulate spatially referenced data.

◊ In the historical context, ever since the seminal study by John Snow in 1856 the idea of mapping disease by place has been an important feature of epidemiology and public health.

◊ GIS technology has evolved within geography and environmental science as a powerful mapping tool with multiple and diverse functions.

◊ There are many possible contemporary applications of GIS in public health. Its potential has already been exploited in a number of different areas including surveillance of infectious disease, mapping of environmental pollutants and in the location of health care services.

The following maps refer to the metropolitan district of Newcastle upon Tyne as defined by the administrative boundaries. Many of the maps use super output areas (SOAs) as the spatial unit of data presentation, others use existing ward boundaries. Lower level super output areas are part of the new census geography based on aggregates of output areas, the smallest grouping in the hierarchy. Output areas cover 100 to 150 households, whilst lower level super output areas contain approximately 650 households. The contextual maps 1-7, which follow, provide background information on singular variables:

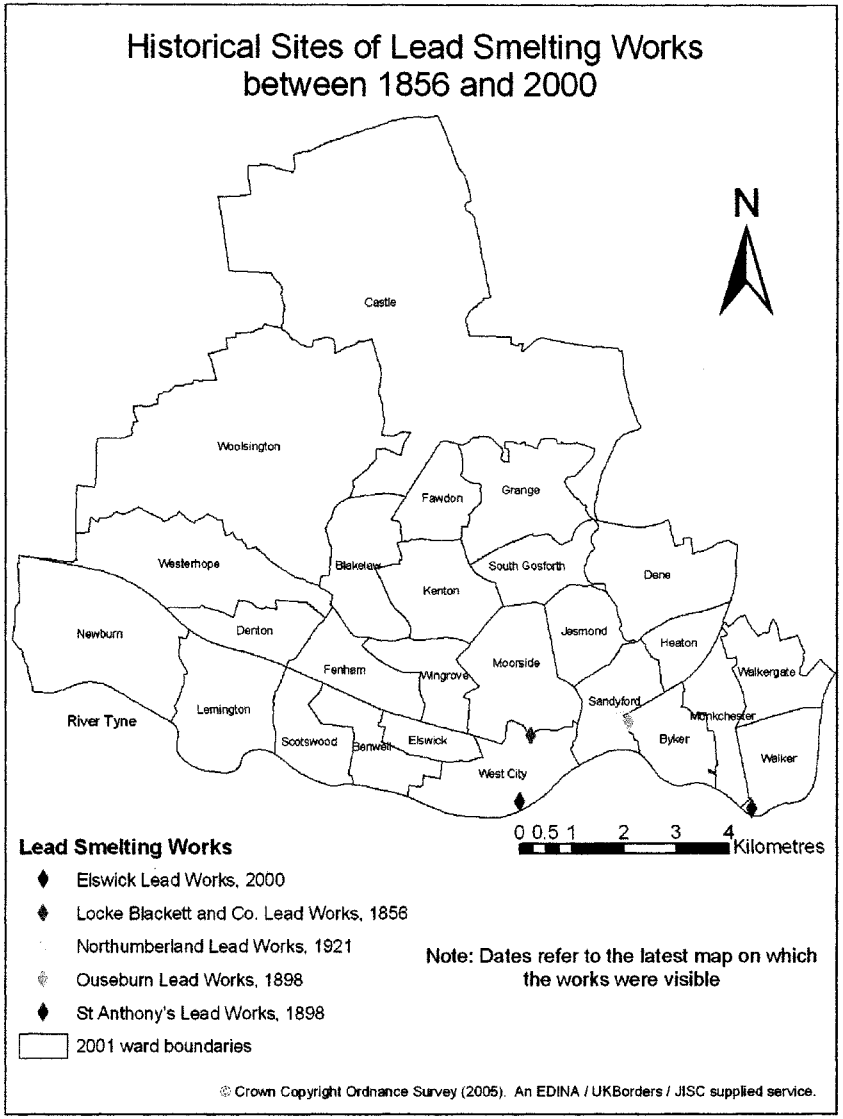
- Contextual Map 1: Historical Sites of Lead Smelting Works;
- Contextual Map 2: Current IPPC Sites;
- Contextual Map 3: Soil Lead Levels (1988);
- Contextual Map 4: Water Lead Levels, (2000 – 2003);
- Contextual Map 5: Population at Risk (Numbers of Children aged 0-4);
- Contextual Map 6: Index of Multiple Deprivation 2004;
- Contextual Map 7:Low Birth Weight by Numbers of Births, 2003.

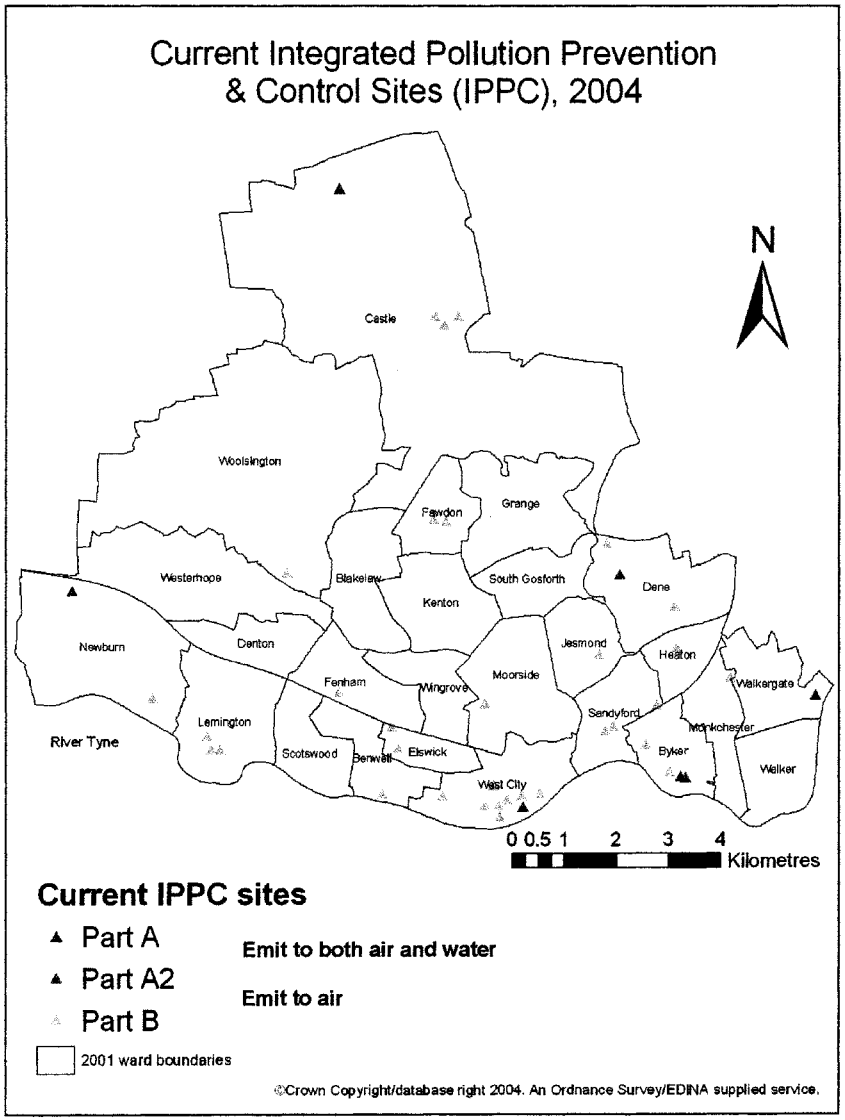
Attention should be drawn to the footnotes of Maps 3 and 4, which relate the environmental data to current approved safety limits as set out by the European Union and the World Health Organisation. The contextual maps can then be used to facilitate interpretation of the more complex map overlays in the final section of the report:

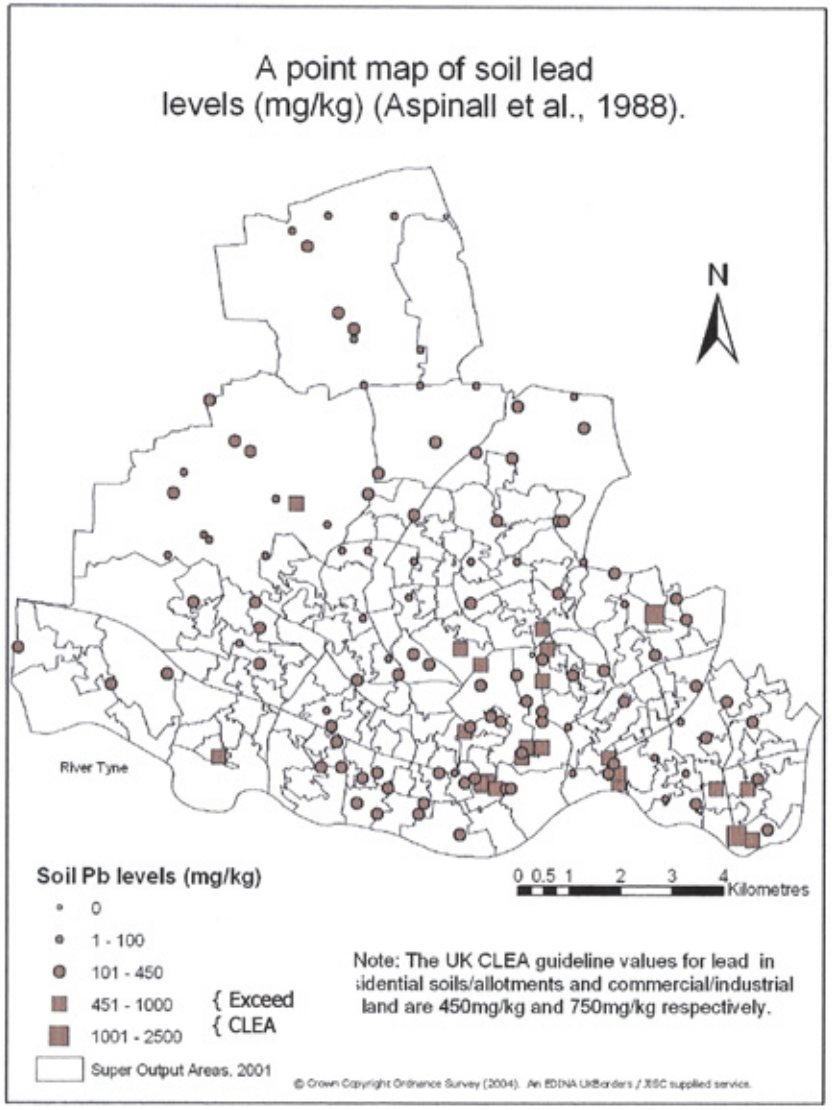
- Overlay Map 1: Soil lead levels and Industry between 1856 and 1898;
- Overlay Map 2: Water lead levels and IMD;
- Overlay Map 3: Low Birth Weight and Soil lead levels;
- Overlay Map 4: School SAT scores and Soil lead levels.

To compare GIS data with more traditional data displays, the data in Overlay 1 is represented in tabular and graphical form on pages 10-12.

Contextual Background Maps






A point map of soil lead levels (mg/kg) (Aspinall et al., 1988).
N
River Tyne
0 0.5 1 2 3 4 Kilometres
Soil Pb levels (mg/kg)
0
1 - 100
101 - 450
451 - 1000
1001 - 2500
{ Exceed { CLEA
Super Output Areas, 2001
Note: The UK CLEA guideline values for lead in residential soils/allotments and commercial/industrial land are 450mg/kg and 750mg/kg respectively.
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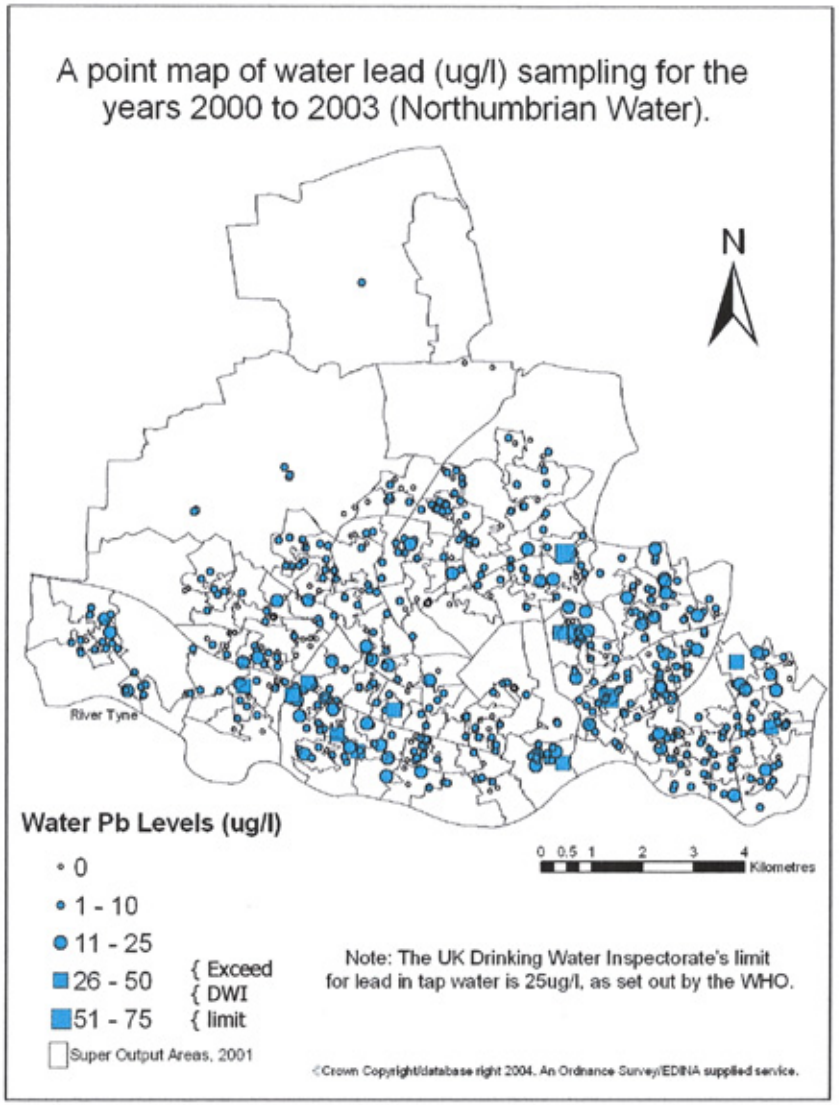
A point map of water lead (ug/l) sampling for the years 2000 to 2003 (Northumbrian Water).
N
River Tyne
0 0.5 1 2 3 4 Kilometres
Water Pb Levels (ug/l)
0
1 - 10
11 - 25
26 - 50
51 - 75
{ Exceed { DWI { limit
Super Output Areas, 2001
Note: The UK Drinking Water Inspectorate's limit for lead in tap water is 25ug/l, as set out by the WHO.
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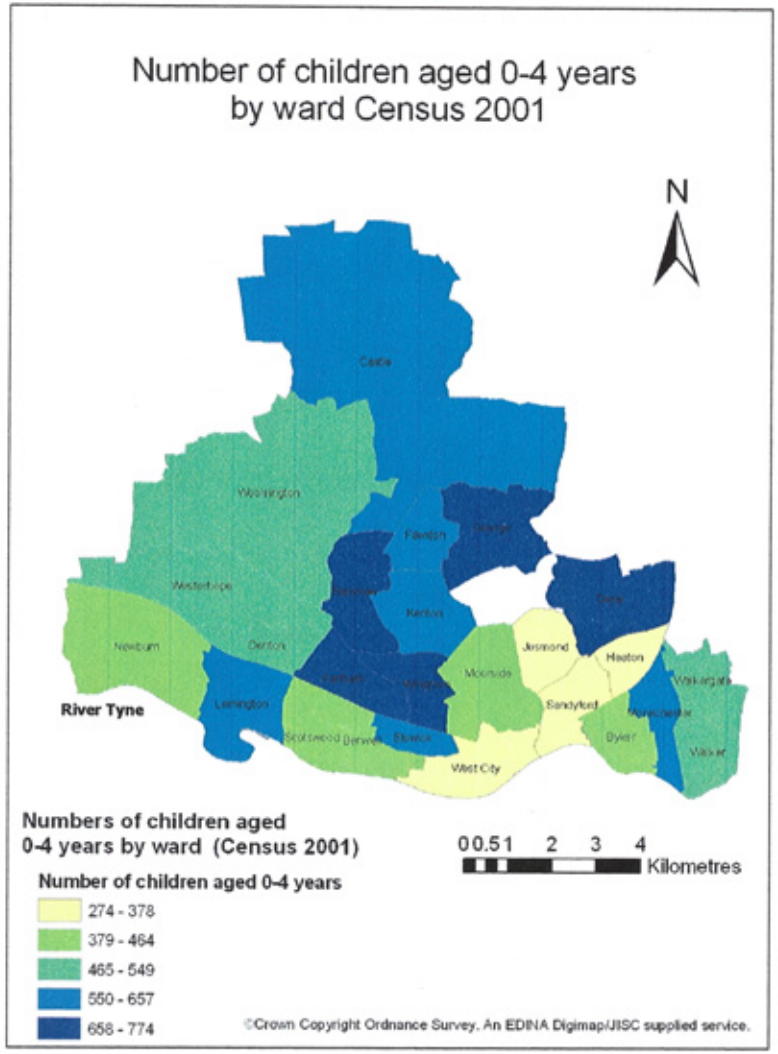
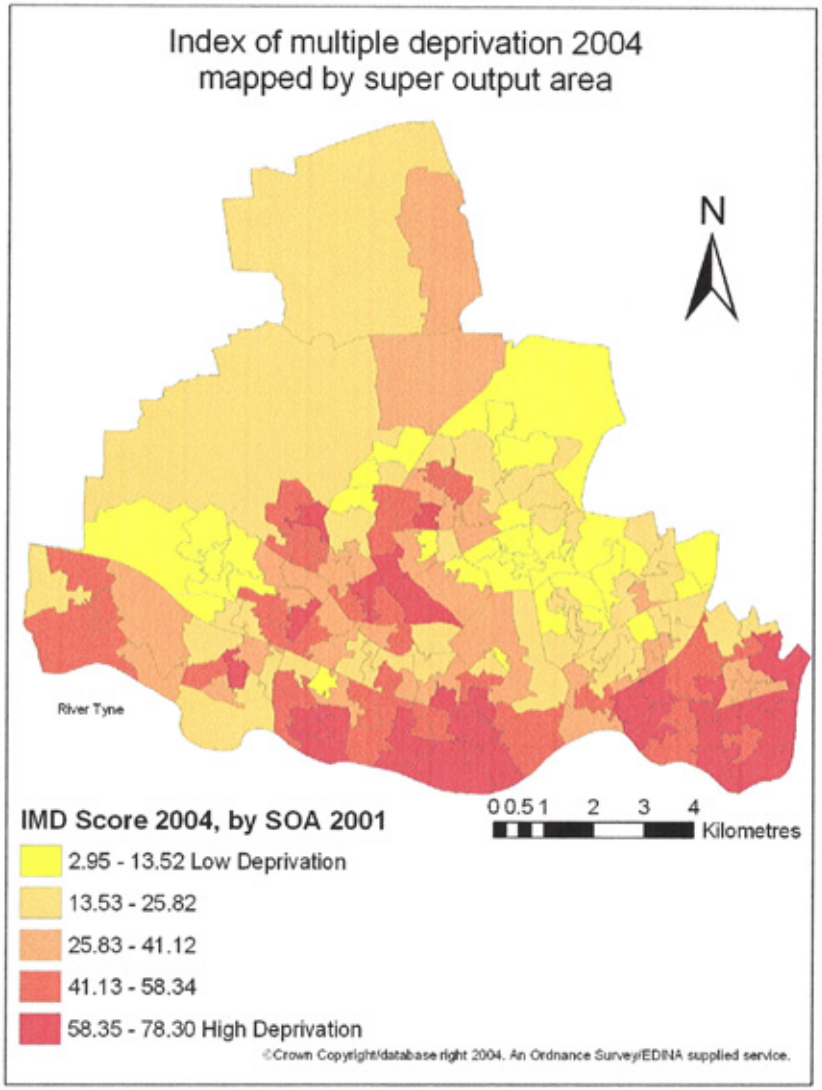
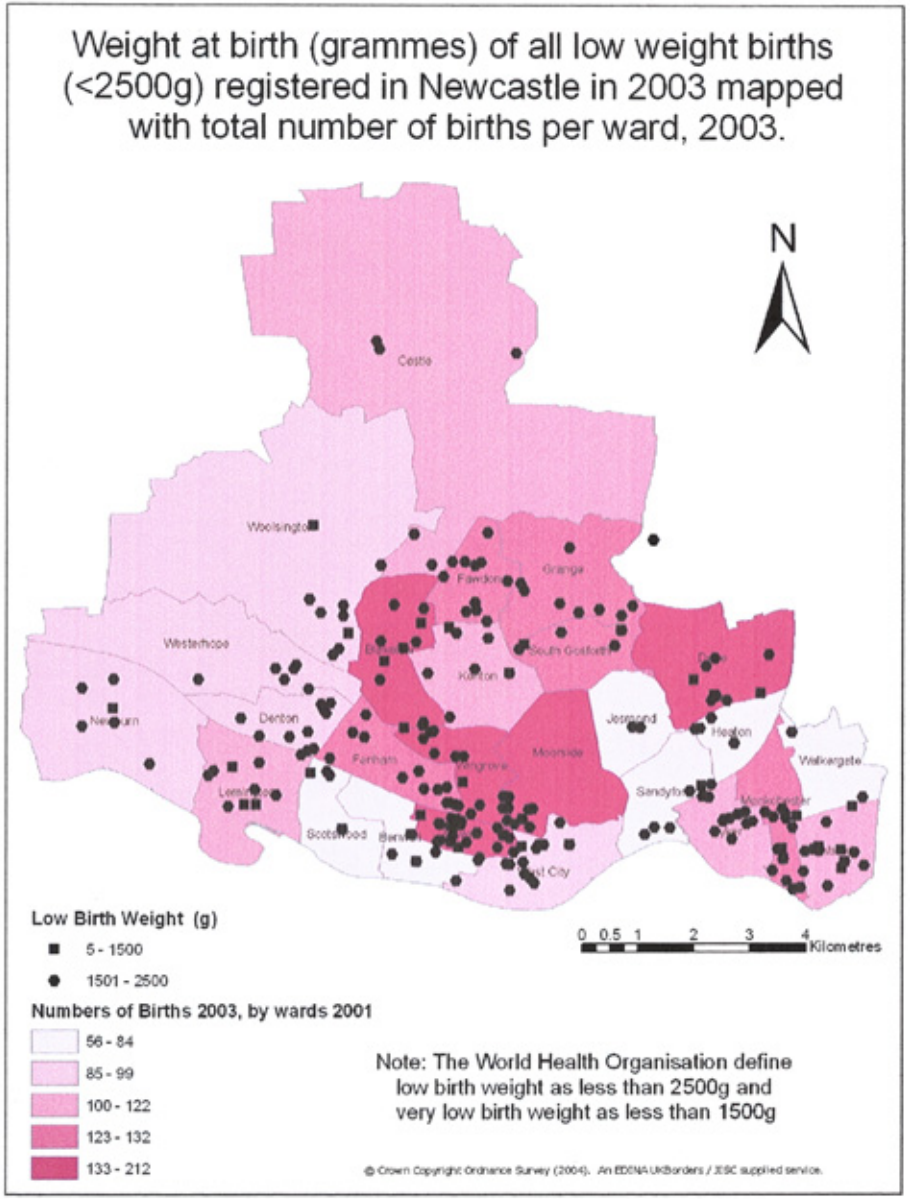


Note: Data are missing for the South Gosforth ward.




Weight at birth (grammes) of all low weight births (<2500g) registered in Newcastle in 2003 mapped with total number of births per ward, 2003.
N
Castle
Woolsington
Fawdon
Grange
Westerhope
South Gosforth
Kenton
Denton
Jesmond
Heaton
Walkergate
Moorside
Sandyford
Low Birth Weight (g)
5 - 1500
1501 - 2500
Numbers of Births 2003, by wards 2001
56 - 84
85 - 99
100 - 122
123 - 132
133 - 212
0 0.5 1 2 3 4 Kilometres
Note: The World Health Organisation define low birth weight as less than 2500g and very low birth weight as less than 1500g
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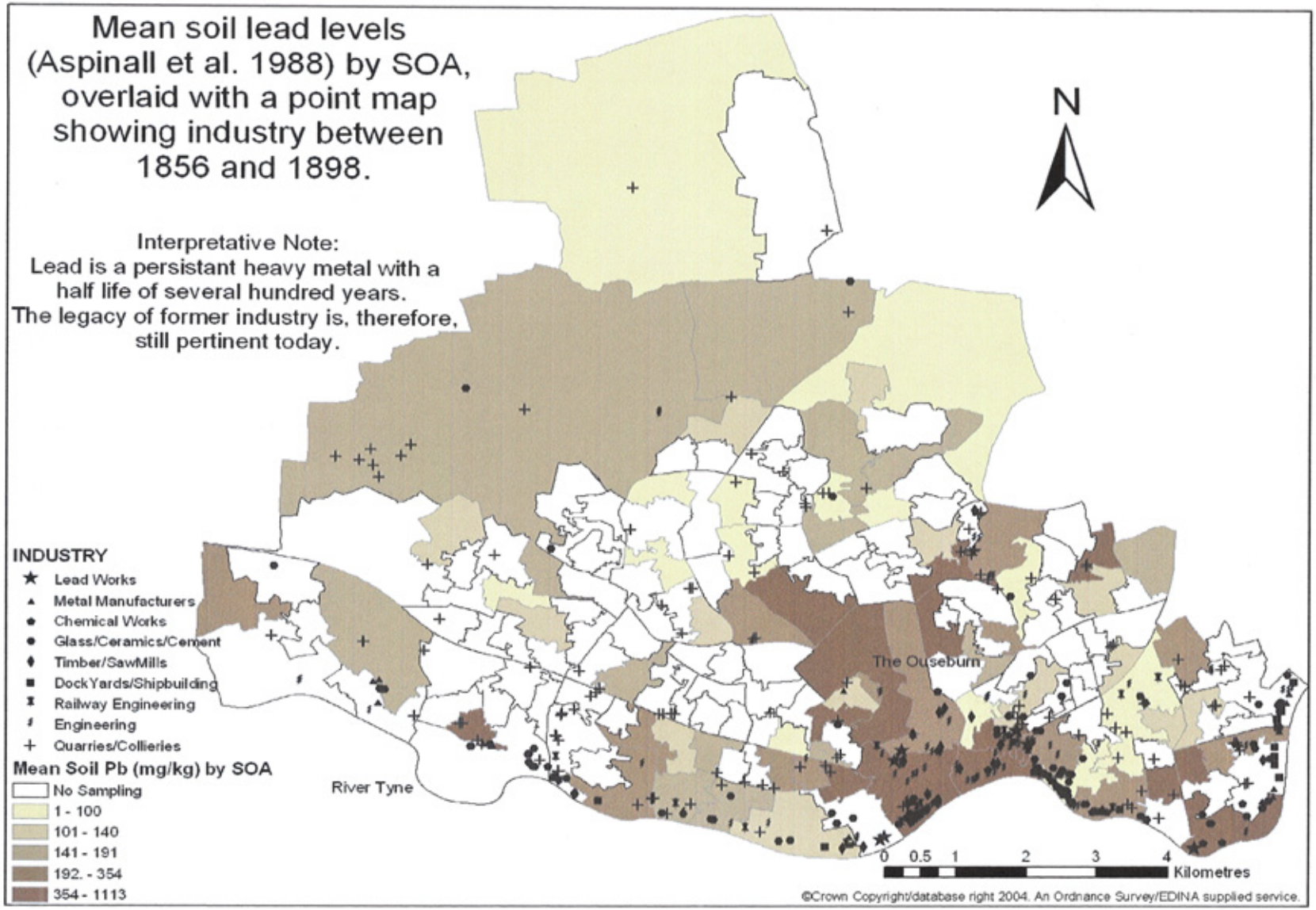
Map Overlays



Tabular representation of data displayed in Map Overlay 1

National Grid Reference		
X	Y	Total Pb Level (mg/kg)
425400	564400	97.0
427000	564700	60.0
427500	565400	48.0
428400	565800	280.0
426200	568300	236.0
425100	567900	106.0
424000	565400	310.0
424800	564900	593.0
424800	567200	1000.0
424900	566800	500.0
424800	566500	173.0
424800	566200	503.0
424800	565500	236.0
414600	566800	200.0
424200	564100	344.0
424100	564100	428.0
417600	569800	133.0
416400	566100	133.0
423900	564100	1000.0
417500	568500	60.0
423600	564200	620.0
418000	567700	133.0
423500	564300	172.0
423300	564200	224.0
418800	570800	375.0
423100	564400	88.0
419200	567700	133.0
422800	564400	200.0
417500	566300	166.0
422500	563800	200.0
420200	574500	133.0
422400	563500	272.0
421100	573000	133.0
421800	564100	224.0

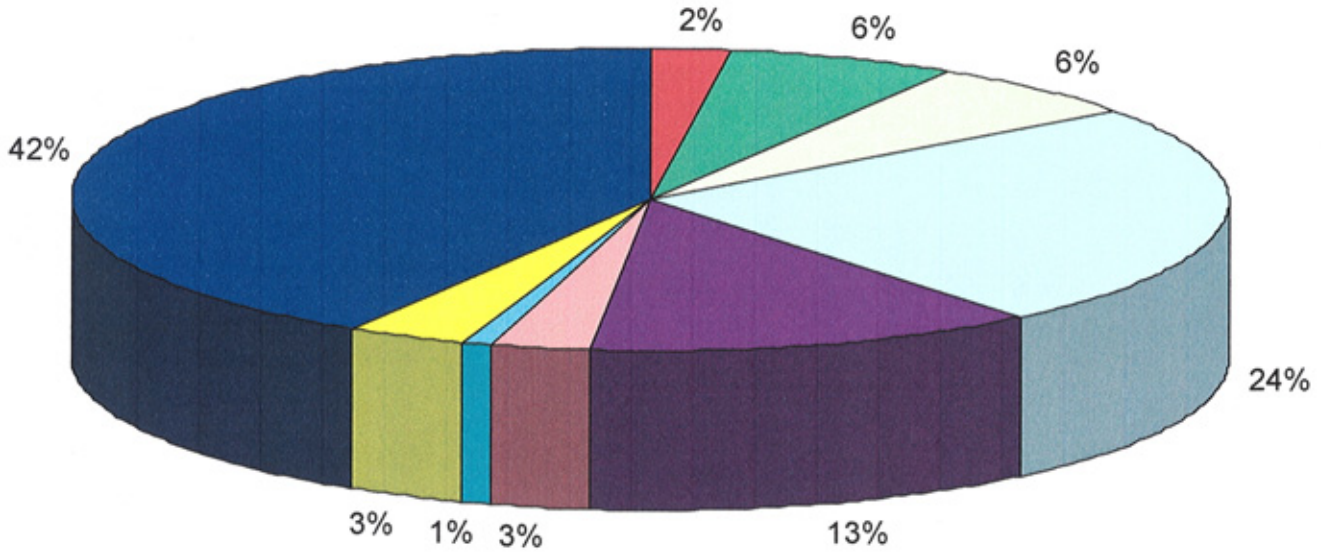
National Grid Reference		
X	Y	Total Pb Level (mg/kg)
423500	571900	80.0
420600	565600	84.0
421200	566200	120.0
421800	566600	70.0
422300	566700	120.0
422600	566500	400.0
423200	566800	550.0
423600	566500	520.0
423600	566100	120.0
424300	566300	160.0
424500	565800	120.0
424800	565400	260.0
424500	564900	460.0
424400	564700	840.0
423800	565500	140.0
423400	565300	200.0
426300	564400	473.0
426100	564700	718.0
426200	564600	284.0
426200	564400	531.0
426100	564400	126.0
426300	564200	913.0
427200	563900	94.0
427800	563800	286.0
427600	564400	61.0
428000	565100	130.0
428800	564100	576.0
429000	564300	194.0
428200	564100	456.0
428600	563200	2414.0
428900	563100	650.0
429200	563300	276.0
428900	565400	118.0
426400	565800	117.0

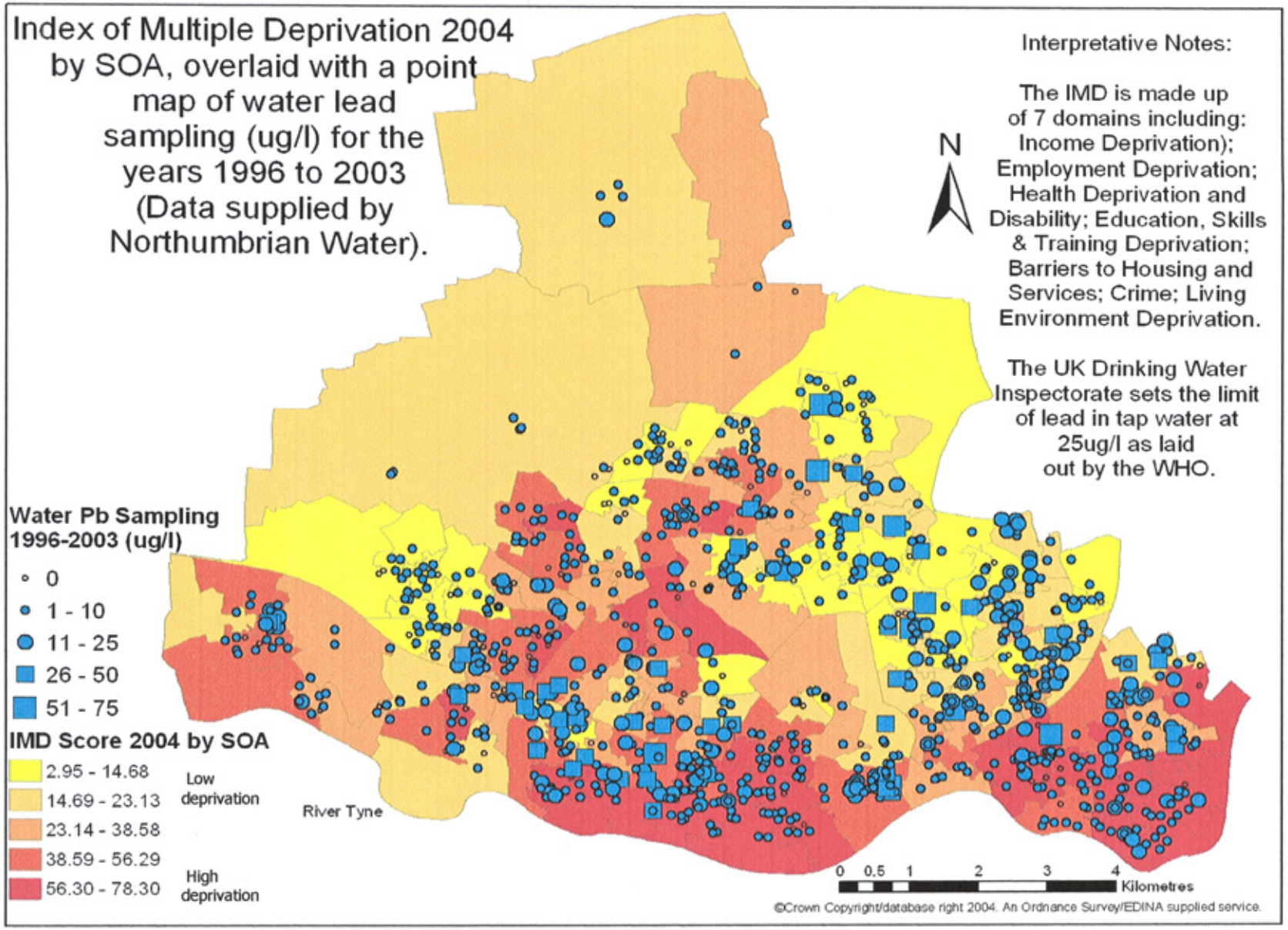
National Grid Reference		
X	Y	Total Pb Level (mg/kg)
422400	571900	78.0
424300	571500	121.0
425400	571700	14.0
419400	568600	100.0
421600	570200	350.0
419600	569700	100.0
420000	569600	575.0
420600	575200	25.0
422900	575200	0.0
418200	569000	75.0
421400	568700	50.0
422400	572600	25.0
418300	568900	25.0
421400	569800	450.0
420900	568700	75.0
421100	572800	25.0
418300	571600	200.0
418500	564700	575.0
419100	570600	125.0
420800	573300	150.0
417800	570200	100.0
421900	575200	50.0
418900	566900	100.0
419300	567200	150.0
419300	566500	125.0
419900	574900	50.0
423200	563200	117.0
420500	564500	436.0
427800	566100	111.0
423700	564200	1305.0
421600	564400	186.0
421600	563600	101.0
427600	567400	181.0
421200	563800	123.0

National Grid Reference		Total Pb Level (mg/kg)
X	Y	
421300	564300	116.0
420900	564500	272.0
420600	569200	96.0
421300	567400	69.0
420800	565000	296.0
422000	566300	166.0
420700	565300	344.0
420700	565300	133.0
424400	564800	330.0
424600	566700	0.0
424200	570500	140.0
424300	568500	50.0
427000	567500	1100.0
427000	566700	140.0
423300	565200	640.0
426000	566400	322.0
425400	566300	171.0
426400	567700	79.0
425600	568500	80.0
423400	567700	189.0
422200	567800	91.0
423400	568500	82.0
422300	568500	97.0
422300	569400	106.0
423900	569300	156.0
425100	569300	158.0
425200	569300	150.0
425600	571100	113.0
423500	570600	119.0
422700	570800	114.0
421300	571900	48.0
425300	565300	97.0
427400	567800	101.0

A pie chart of industries between 1856 and 1898

Graphical representation of data displayed in Map Overlay 1




Index of Multiple Deprivation 2004 by SOA, overlaid with a point map of water lead sampling (ug/l) for the years 1996 to 2003 (Data supplied by Northumbrian Water).
Interpretative Notes:
The IMD is made up of 7 domains including: Income Deprivation); Employment Deprivation; Health Deprivation and Disability; Education, Skills & Training Deprivation; Barriers to Housing and Services; Crime; Living Environment Deprivation.
The UK Drinking Water Inspectorate sets the limit of lead in tap water at 25ug/l as laid out by the WHO.
N
Water Pb Sampling 1996-2003 (ug/l)
0
1 - 10
11 - 25
26 - 50
51 - 75
IMD Score 2004 by SOA
2.95 - 14.68
14.69 - 23.13
23.14 - 38.58
38.59 - 56.29
56.30 - 78.30
Low deprivation
High deprivation
River Tyne
0 0.5 1 2 3 4 Kilometres
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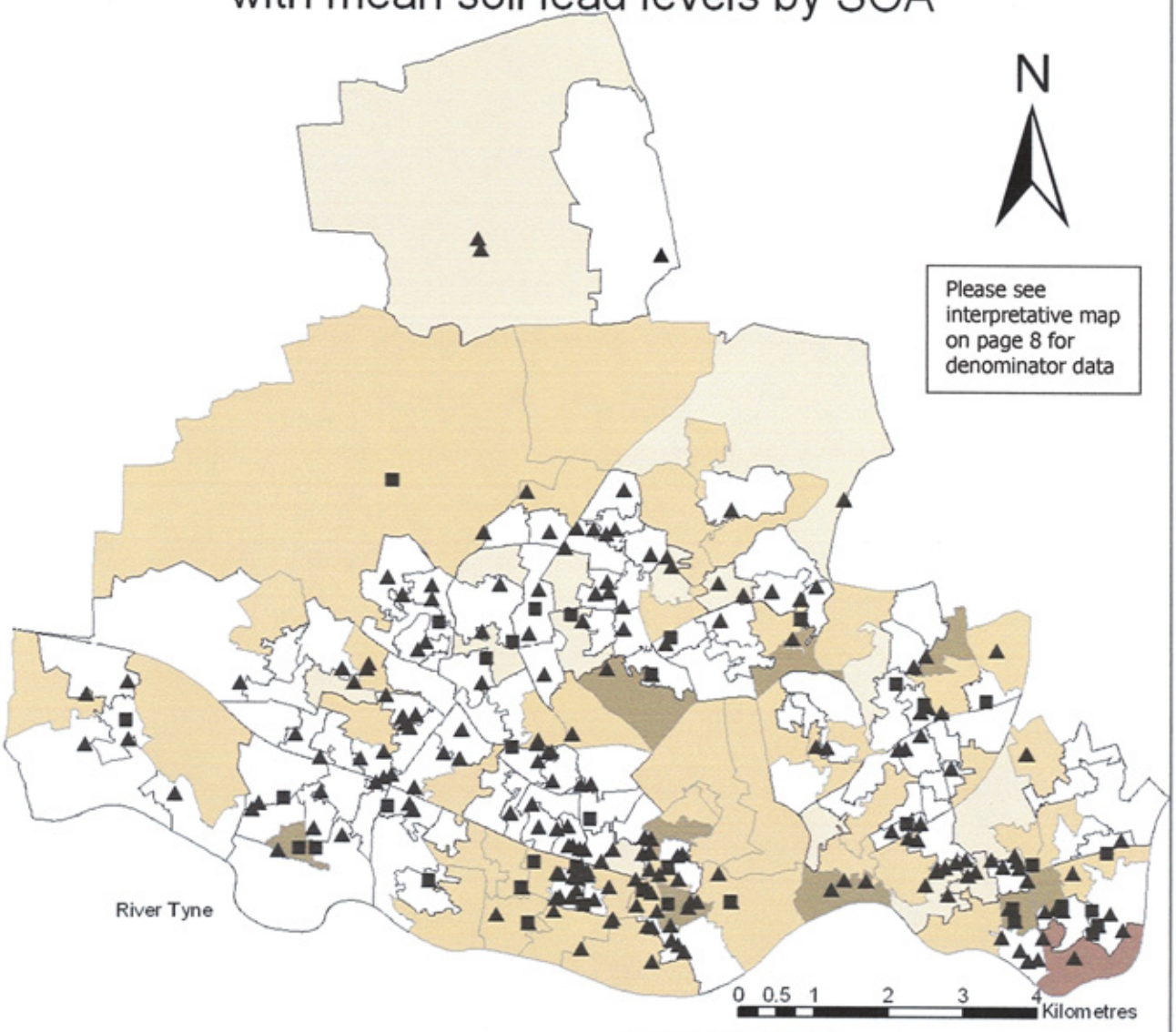
Weight at birth (grammes) of all low weight births (<2500g) registered in Newcastle in 2003 mapped with mean soil lead levels by SOA



Low Birth Weight (g)

- ■ 5 - 1500
- ▲ 1501 - 2500

Mean Soil Pb Level (mg/kg)

- No Sampling
- 1 - 100
- 101 - 450
- 451 - 1000
- 1001 - 1200

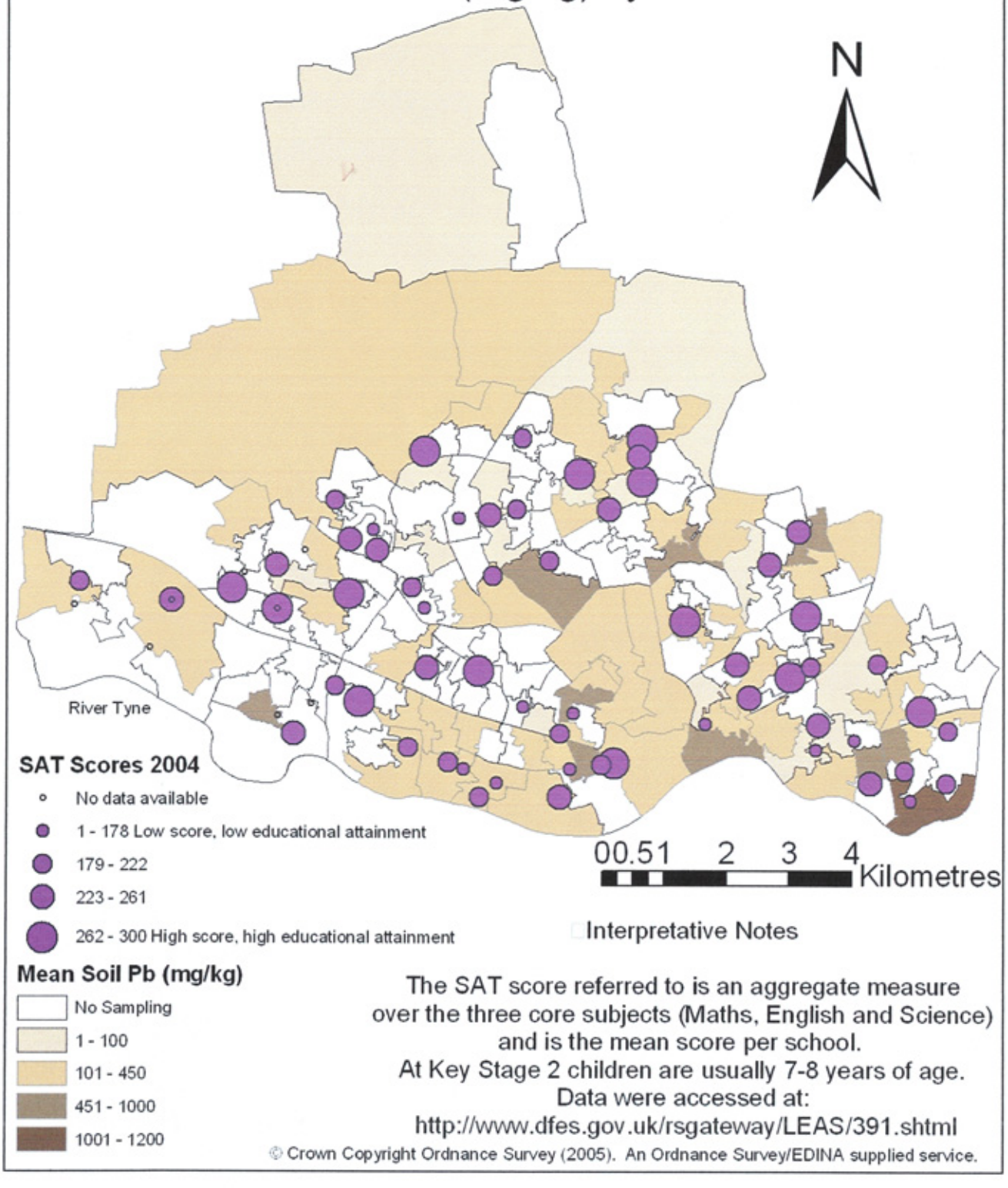
Interpretative Notes:

The World Health Organisation define low birth weight as less than 2500g and very low birth weight as less than 1500g.

Low birth weights will include multiple births. The proportion of multiple births in Newcastle, however, tends to be low (2.81% in 2003).

Similarly, it is known that birth weight is lower in BME groups. The demographic profile of Newcastle shows that BME representation is fairly low in the city with most BME communities living in the west end, Fenham, Benwell etc. or in Heaton, a ward with a large student population.

Average school SAT scores at Key Stage 2 for 2004 overlaid with a choropleth map of mean soil lead levels (mg/kg) by SOA.



Key Literature Sources

Canfield, R.L., Henderson, C.R., Cory-Slechta, D.A., Cox, C., Juski, T.A., Lanphear, B.P. (2003). Intellectual Impairment in Children with Blood Lead concentrations below 10 μg per Deciliter. *The New England Journal of Medicine*, **348**, 1517-1526.

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Mellor, A. (2001). Lead and zinc in the Wallsend Burn, an urban catchment in Tyneside, UK. *The Science of the Total Environment*, **269**: 49-63.

Thornton, I. Rautiu, R. & Brush, S. (2001). *'Lead: the facts'*. London: Imperial College Consultants Ltd.

Valent, F., Little, D., Bertollini, R., Nemer, L. E., Barbone, F. and Tamburlini, G. (2004). Burden of disease attributable to selected environmental factors and injury among children and adolescents in Europe. *Lancet*, **363**, 2032-2039.

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Appendix II: The Case within the Case

The case within the case: Childhood Lead Exposure in Newcastle upon Tyne

Introduction

The heavy metal, lead, is omnipresent in the environment on a global scale, due to its involvement in a number of anthropogenic processes. It is a bluish white metallic element, which forms the alloys pewter and solder (Parker, 1996) and has a halflife in soil of several hundred years (Thornton, 1998). Contemporary research in Australia and the United States has associated the heavy metal lead (Pb) with cognitive impairment and behavioural problems in children and has shown that exposure and uptake are related to socio-economic status (Canfield *et al.,* 2003; Tong *et al.*, 1996). The health effects of lead are not distributed evenly throughout different socio-economic groups and children with pre-existing nutritional deficiencies living in areas with multiple sources of lead contamination tend to be disproportionately affected (Centers for Disease Control and Prevention, 2000). In the UK, however, little up to date epidemiological information is available on:

(i) the risk of lead to children;
(ii) the physiological effects of lead;
(iii) the distribution of lead geographically and throughout the social strata.

The purpose of this appendix is to review the contemporary literature base relating to the issue of childhood lead exposure to provide a justification for the timeliness and suitability of this case example within the case study. The review examines the issue of childhood lead exposure using a broad, multifaceted approach by outlining the problem from biomedical, environmental and socio-economic perspectives. The review concludes in

---

The Environmental Context

Lead is a persistent heavy metal found in a number of sources throughout the environment including soil, water, household dust and air. The main sources of lead in the environment are mining, smelting, plumbing, vehicle emissions and the manufacture and use of lead based paints. In addition to anthropogenic processes, lead is discharged into the environment naturally as a result of activities such as the weathering of rock, volcanic activity and forest fires (Thornton, 1998). The phase out of lead in petrol has greatly reduced atmospheric lead levels and is viewed as one of the major success stories in public health (Valent, 2004). The persistent nature of lead, however, means that lead from vehicle and industrial emissions released into the air and deposited in soils, before abatement procedures were introduced, still remains a problem.

With the present UK government encouraging the redevelopment of brownfield sites (land previously used for industrial purposes) the legacy of contamination from former industry becomes an important issue (DEFRA, 2003). Over the years various different heavy industries have contributed to soil pollution so much so that it is often difficult to trace soil contamination back to a specific point source (Aspinall, Openshaw and Macklin, 1988). The Contaminated Land Exposure Assessment model (CLEA), developed in 2002, define the soil guideline value for lead in soil as 450mg/kg for residential uptake and allotments and 750 mg/kg for commercial or industrial land (Vizard and Pless-Mulloli, 2003).

A survey by Thornton and associates (1990) conducted in the United Kingdom in the 1980s measured lead contamination in household dusts and garden soils. Until 1992 lead was commonly used as an additive in paint and therefore is often found in household dust. The geometric mean concentrations of lead were 266μg/g and 561μg/g in garden soil and household dust respectively. Approximately 10% of floor dusts were found to exceed 2000μg/g leading the authors to conclude that ingestion of household dust is an important exposure pathway. Samples were collected in Newcastle and the geometric mean concentration for house dust and soil samples were similar to the national averages. The concentration of lead in household dust was found to increase with house age. Overall concentrations of lead in house dust were almost double those in soil, which suggested that the origin of the lead was internal, perhaps from leaded paint. This finding is in agreement with much of the American literature which shows that house dust contaminated with lead based paint debris represents the major route of lead exposure in children. In the study described here, soil data will be mapped along with data on house age as a proxy indicator of houses likely to have leaded paint or pipes *in situ*.

Lead piping was used in water systems until the 1960s when copper (a metal with an even lower reactivity than lead) was introduced. The plumbosolvency of water (the capacity of water to dissolve lead from pipes) is determined by two factors: temperature and pH. Lead tends to be leached readily by soft, acidic water and by hot water (Thornton, Rautiu & Brush, 2001, p90). Hard water (basic, pH > 8) from ground water supplies has a protective effect as calcium carbonate deposits effectively line the pipe. In Newcastle, the water supply is hard but leaching of lead from pipes can still occur at a slower rate. Northumbrian water implement a system of phosphate dosing (the addition of orthophosphate to soft water supplies) to reduce plumbosolvency (http://www.nwl.co.uk/env04/custDrink.asp?channel=5&top=47&header=125#909). Lead piping is still in existence today in mains and service pipes and household plumbing. Of particular concern is the length of pipe stretching from the property to the mains supply, this stretch (the service pipe) is the responsibility of the home owner (http://www.nwl.co.uk/content/yourWater.asp?channel=1&top=2&header=34&collapse=86#329).

A study by the Scottish Executive Health Department (2000) surveyed water lead levels in recently built houses in Scotland to determine the proportion of homes where lead solder had been used in the drinking water plumbing system. Lead from solder can be leached into drinking water by galvanic corrosion and treatments such as phosphate dosing which are effective in abating plumbosolvency have been shown to have little effect in reducing corrosion of lead from solder. The use of lead solder in household plumbing was banned in Scotland in 1987 but evidence came to light that a number of building and plumbing firms in Scotland were contravening the Water Bylaw (Scottish Centre for Infection and Environmental Health, 2000).

Ninety nine of the 661 houses (15%), built between 1997 and 2000, randomly tested had at least one sample where the lead level was above the threshold value of $5\mu gl^{-1}$. Three different sites were sampled per house: the kitchen cold water tap, a bathroom cold water tap and a bathroom hot water tap. Water lead levels were above the new "regulatory" water standard in 16 samples from cold water kitchen taps, 36 from cold water bathroom taps and 27 hot water bathroom taps. The authors of the report draw attention to the number of cold bathroom supplies with elevated lead as being "particularly relevant for water consumption by children". There have been no recent water

lead surveys such as this conducted in England. The study presented here draws together existing data on water lead levels supplied by Northumbrian Water to address this gap in the data for Newcastle upon Tyne. The patterning of lead throughout the social environment is reviewed in the following section.

The Social Context

The observation that inequalities in health often reflect the uneven distribution of wealth throughout populations has been recognised for some time. The seminal work of the sanitarian Chadwick in the mid 19th century uncovered the inter-relationship between poverty and disease and showed how both the physical and social environment can affect health status (Rosen, 1958, p. 209). Krieger (2001) notes that these associations were appreciated much earlier still in the Hippocratic corpus and in texts of ancient Chinese medicine. Recent evidence suggests that inequalities persist within communities in the UK and that these disparities are continuing to widen (Shaw *et al.*, 2001). The issue of population exposure to environmental lead has also been linked to deprivation and adverse socio-economic conditions. Smith (1998) observed in a report for the Institute of Environmental Health that 'lead uptake in children in urban populations is not random but highly co-linear with disadvantage'. Newcastle is part of the urban conurbation of Tyne and Wear and as a district contains 56 out of a total of 173 super output areas (SOAs) which are within the most deprived 10% of SOAs in the country (http://www.newcastle.gov.uk/pr.nsf/a/IMDAnalysis).

There is likely to be a gradient of contamination across cities or within specific urban localities, which may be reflective of underlying disparities in terms of socio-economic wealth. Disadvantaged communities are more likely to live in older housing, where lead pipes and lead based paint may still be in existence. These areas also tend to be industrialised or to contain sites of former industry as well as major road systems. In addition, children living in deprived areas may have dietary deficiencies, in which case the uptake and adverse effects of lead could be exacerbated (Mahaffey, 1995). As already discussed Newcastle contains three times the expected number of SOAs falling within the most deprived 10% of SOAs countrywide so issues relating to socioeconomic disadvantage and lead exposure are especially pertinent.

Brown (1994) makes a valid point that often a number of forces can act in synergy to increase exposure to an environmental hazard, for example exposure at home, at school, or via parental occupation. In prospective, longitudinal studies the adverse effects of lead on intellectual development and behaviour have been shown to result in reduced educability (Tong *et al.*, 1996; Tong, McMichael and Baghurst, 2000), which could potentially impact on an individual's future employability thereby limiting their chances of relocating to an area where lead contamination is not a problem. The effects of lead in this way are cyclical so the problem can be compounded and reinforced generation after generation.

In the United States, the National Health and Nutrition Examination Surveys (NHANES) have monitored the impact of lead as a public health risk since the 1970s. Population groups at a higher risk of exposure to lead were identified as 'people with low income, people of non-Hispanic black race and people who live in older housing' (Pirkle *et al.*, 1998). Accordingly the Centers for Disease Control and Prevention advocate a targeted surveillance screening

programme focussing on low income families enrolled on Medicaid[1] and children living in pre-1950s housing (Centers for Disease Control and Prevention, 2003). In the UK there is no comparable national survey and no up to date, reliable and representative data on the extent of lead exposure in different demographic groups.

Valent and associates (2004) suggest that strategies to prevent lead exposure should be tailored towards the whole population but resources should concentrate on high risk groups including individuals living in 'hazardous' housing who are exposed to lead pipes and lead paints. In Newcastle such areas would include the traditionally deprived riverside wards in the South of the district (Elswick, Scotswood, and Benwell) which unsurprisingly have contained the most industrial sites and to the east of the city wards such as Byker, Walker and Walkergate which contain super output areas included in the 10% of most deprived SOAs in the country . The effects of lead on the health and development of children are reviewed in the following section to demonstrate the importance of lead as a highly toxic but preventable environmental contaminant.

The Health and Development Context

The heavy metal lead (Pb) is ubiquitous in the environment but has no known use in the body (Millstone, 1997). In the environment lead can spread from source to receptor by inhalation, but more significantly by ingestion, and is thought to exhibit a spectrum of physiological effects depending on the level of exposure (Prasad and Nazareth, 2000). Acute effects include anaemia, anorexia, fatigue, depression, vomiting and in cases where the level of exposure is high (> $70\mu gdL^{-1}$) serious neurological conditions such as seizure, coma, encephalopathy and even death (Institute for Environment and Health, 1998; Prasad and Nazareth, 2000; Meyer *et al.*, 2003).

Exposure to lead over prolonged periods of time has been linked to hypertension (Batuman *et al.*,1983; Institute for Environment and Health, 1998), gastrointestinal conditions (Prasad and Nazareth, 2000) and renal insufficiency in adults (Batuman *et al.*,1983, Lin *et al.*, 2003). In children there is evidence associating lead exposure with behavioural problems (Lewendon *et al.*, 2001), developmental disturbances (Needleman *et al.*, 1990; Shen, Wu and Yan, 2001) and cognitive impairment (Canfield *et al.*, 2003; Centers for Disease Control and Prevention, 2000; Tong *et al.*, 1996).

Lead is an accumulative toxin, which tends to be deposited in the skeletal system where it can persist for decades (Millstone, 1997). Blood lead levels are used to measure acute lead exposure but bone tends to be a more reliable indicator of prolonged low level exposure (Han *et al.*, 2000). Mahaffey (1995) states four nutritional conditions that augment the physiological effects of lead uptake, namely irregular food intake, high fat intake, and deficiencies in calcium and iron. The relationship between lead and iron is a cyclical one. Iron deficiency increases lead uptake (Mahaffey, 1995). Once in the body, lead can interfere with Fe^{2+} or Fe^{3+} dependent processes at the cellular level, which can then increase active transport into the body (Bradman *et al.*, 2001). Substitution of Fe^{2+} with Pb^{2+} in blood cells can decrease the rate of lead excretion therefore increasing endogenous body lead burden further (Bradman *et al.*, 2001). It has also been suggested that conditions such as pica can be aggravated by iron

[1] Medicaid is a federal and state health insurance program established to enable access to health care services for individuals on low income.

deficiency so a child could potentially increase his or her uptake of lead (Scott and Cochran, 2002). The associations between poverty and nutritional deficiencies and nutritional deficiencies and lead uptake underline environmental and social equity issues. Nutritional deficiencies alone do not cause lead uptake rather it is the compounding burden of interrelated factors often associated with poverty such as substandard housing, proximity to industry and major road networks.

In the United States any blood lead level (PbB level) above $10\mu gdL^{-1}$ is considered to be potentially harmful and lead intoxication is defined as a case where PbB level is measured to be over $25\mu gdL^{-1}$ (Centers for Disease Control and Prevention, 1998). Evidence is emerging to suggest that the effects of lead can be observed at levels as low as $10\mu gdL^{-1}$ (Canfield *et al.*, 2003). At present, the absence of routine blood lead surveillance in this country means that only the extreme cases of lead exposure (*i.e.* poisonings) are recorded. There are no routinely available data on sub-toxic blood lead levels, which might affect health and development (Health Protection Agency, 2004).

Elliott and colleagues completed an analysis of routine sources of data (mortality statistics, hospital admission records, reports to the Health and Safety Executive and analyses from Medical Toxicology Units) to determine the frequency of clinical lead poisoning in England and Wales for the period from 1981 to 1997. They concluded that overall cases of lead poisoning in England are "rare" but some spatial clustering of cases was observed. Interestingly in over half of the cases of lead poisoning in children under 5 years of age the child came from the most deprived quintile of electoral wards. This evidence provides support for the hypothesis that environmental lead contamination follows the patterning of economic deprivation. This proposition is investigated in the mapping phase of the study

The Port Pirie prospective cohort study is one of a small number of longitudinal studies conducted to examine the effects of lead exposure on children's intelligence over time. The researchers demonstrated that 'verbal, performance and full scale IQ were inversely related to blood lead concentration' (Tong *et al.* 1996; p1569). It is widely accepted that lead is associated with reductions in cognitive ability and educability in children but difficulties exist in establishing causality. The complexity of the problem lies in the number of confounding factors involved. In a cross-sectional study based in Edinburgh, Raab and associates (1985) identified a number of confounding variables when examining the association between exposure to low levels of environmental lead and performance in psychological tests. These included parental occupation and psychological test scores, the child's position in the family, separation from parents and the overall health of parents and child. Other factors such as household income and nutritional status of the child might also act as putative confounders or effect modifiers thus demonstrating that the issue of childhood lead exposure is more complex than just the interplay of the child between his or her immediate physical environment.

In a systematic review of studies examining the association between environmental lead exposure and intelligence loss, Pocock, Smith and Baghurst (1994) contend that there might be a case for reverse causality. In other words they suggest that it is possible that children of lower intelligence might engage in activities that increase their exposure to lead. Pocock and colleagues conclude that the complexity of the phenomenon and the array of confounding factors involved means that other explanations for IQ deficit are possible. The authors could be criticised for ignoring the wider determinants of the issue by

thinking down stream and endorsing a victim blame culture. They fail to recognise that lead exposure is not a lifestyle choice rather it is a societal issue and the populations who are most at risk from exposure are least likely to have the resources to abate the problem. In this study the wider determinants of the issue are taken into account by exploring the distribution of lead throughout the socio-economic strata in Newcastle.

Following the work of Pocock *et al.*, Jones (1995) challenges that the effects of lead are unique compared to other neurotoxins in that the "gap between what is typical and what is toxic" is unusually narrow, therefore any observed effect on cognitive ability demonstrated in epidemiological studies would be relatively small. In this way the results reproduced in several studies associating lead exposure with an IQ deficit of 1-2 points agree with what would be expected if lead was having an adverse effect on development in children.

A number of studies have examined the association between low birth weight and prenatal lead exposure (Falcon, Vinas and Luna, 2003; González-Cossío *et al.*, 1997; Han *et al.*, 2000; Schell *et al.*, 2003). Lead can be mobilised from bone into plasma during pregnancy and is therefore available to cross the placenta (Schell *et al.*, 2003). Lead from historical as well as current exposures can increase the maternal body lead burden and pose a risk to foetal development (Han *et al.*, 2000). The industrial heritage of Newcastle upon Tyne and the range of sources of environmental lead suggest that maternal lead body burden may be a significant exposure pathway for the unborn child. Population data relating to morbidity rather than mortality are scarce (Unwin *et al.*, 1997, p49). Lead is thought to exhibit effects on several physiological systems in the body as discussed earlier but many of these effects are innocuous and therefore unmeasured.

The Importance of Children

It is widely accepted that children's health is largely dependent on their living environment and there is an increasing understanding that individual lifestyle choices are not as dissociated from over-riding, non-controllable environmental and political influences as previously thought (Lanphear, 2005). Smith, Corvalan and Kjellstrom (1999) (cited in Valent *et al.*, 2004) estimate that at least 40% of the global environmental burden of disease affects children under the age of 5 years. The reasons for children being especially vulnerable to lead exposure and uptake are multi-fold. First, their organs are rapidly developing and are therefore susceptible to disruption by chemicals or other toxic agents. The intricate processes involved in neurological development are thought to be particularly vulnerable to such effects. Second, absorption in the digestive system is a more efficient process in children compared with adults so any toxins ingested are disseminated more rapidly (Jarosinska, Peddada and Rogan, 2003). Third, infants and young children exhibit specific behaviours such as hand to mouth activity, frequently observed in many children and less common behaviours such as pica[2] that increase their chances of lead uptake (Thornton *et al.*, 1990). The extent of exposure might be prolonged or repeated to increase uptake and augment total body burden. Finally the vulnerability of infants and children is compounded as children have less control over their environment than adults and are therefore at a disproportionately greater risk to environmental hazards.

[2] Pica is a behaviour characterised by the ingestion of non food items.

Aynsley-Green and associates (2000) maintain that the health needs of children are distinct from those of adults and recognise that the well being of children is vital to ensure the health of future generations. It is also widely accepted that disadvantage experienced during childhood can impact on health status in later life (Davey Smith *et al.*, 1998) and adult patterns of morbidity have been associated with childhood disease exposures (Aynsley-Green *et al.*, 2000) and foetal programming[3] (Godfrey and Barker, 2001). With these points in mind, Aynsley-Green and colleagues argue the need for effective advocacy to protect the fundamental human rights of children who often lack a voice in the government's health agenda. They contend that all children should be properly represented in central and local government policy (Aynsley-Green *et al.*, 2000).

Children living in deprived areas are most likely to encounter health problems but are least likely to have their rights supported. A recent UNICEF report on 'Child Poverty in Rich Countries' showed that 15.4% of children in the United Kingdom live in relative poverty defined as 'households with income below 50% of the national median income' (UNICEF, 2005). In Newcastle, 56 out of a total of 173 super output areas (SOAs) are within the most deprived 10% of SOAs in the country (http://www.newcastle.gov.uk/pr.nsf/a/IMDAnalysis). It is clear that child poverty is a major issue of concern and despite the government's promise to reduce child poverty in this country, levels remain unacceptably high. The relationship between lead exposure and economic disadvantage will be discussed in section 3.4 and is a central theme in the project.

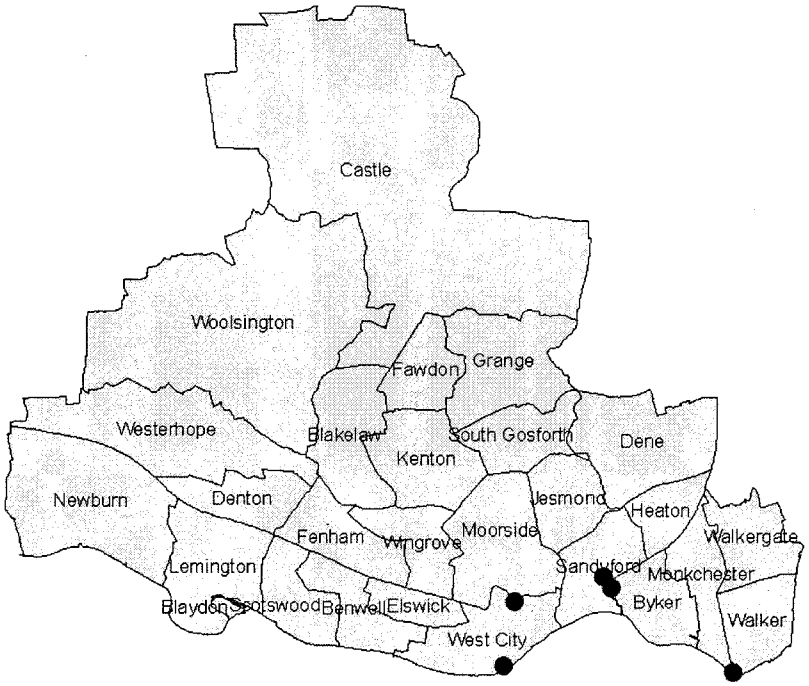
The study area

The study area is defined as the administrative boundaries of the district of Newcastle upon Tyne as shown in figure 1 (NG Easting, Northing 425 500, 564 500; NG 1km square NZ 2564)[4]. The district covers an area of 112km^2 (Newcastle City Council) with a population of around 266,600 (mid year estimate 2003 based on Census 2001, Newcastle City Council). Newcastle has a long industrial history with coal mining, ship building, heavy engineering and manufacturing being central to the region's economy (Institute for Environment and Health, 1998; Mellor, 2001). Exploitation of the underlying coalfields contributed to the city's prosperity in the 19th and early 20th centuries. Five major lead smelting and finishing works have been sited in Newcastle since the Industrial Revolution, including Lock Blacketts in Gallowgate (424384, 564335), St Anthony's Lead Works (428633, 562956) and Ouseburn Lead Works (426112, 564818) and Northumberland Lead Works (426270, 564600) both in the Ouseburn area and Calders in Elswick (424180, 563085).

[3] Foetal programming is the term used to describe the process whereby nutritional or endocrine changes during intrauterine growth cause long term effects which predispose the individual to chronic diseases, such as coronary heart disease in adult life.

[4] NG stands for National Grid and refers to the metric grid based system based on the Tranverse Mercator Projection developed by Ordnance Survey (1936) and used for mapping purposes in the United Kingdom.

Figure 1: Map showing the locations of former lead works within the administrative boundaries of Newcastle upon Tyne



The study was supported by the Newcastle Lead Task Force Group, an interagency working group involving representatives from the Health Protection Agency, Newcastle City Council, the Local Strategic Partnership, Northumbrian Water and the Universities of Newcastle and Northumbria. The Newcastle Lead Task Force highlighted a need to discover whether or not lead was (still) a public health problem in Newcastle upon Tyne. As well as contributing to local knowledge, the results of the PhD study presented here will feedback to the Lead Task Force Group to inform the design of further analytical studies.

Appendix III: Participant Information Sheet

Participant Information Sheet

Thank you for agreeing to read this information sheet describing my PhD study which examines how geographical information systems can contribute to the evidence base for decision-making in public health, using childhood lead exposure in Newcastle upon Tyne as the case example. The study is funded by Northumbria University.

Background information

The idea of 'evidence-based decision-making' is politically in vogue and the terms are omnipresent in recent government publications. Geographical information systems (referred to from here on in as GIS) represent a means for integrating and combining multiple and disparate datasets and there is potential for such systems to facilitate interagency collaboration at the strategic as well as the theoretical level. The power of GIS as a means to incorporate multiple divergent facets of a problem is well suited to the field of public health research where contemporary health issues are considered using a broad ranging model.

Purpose of the Study

The study is a bipartite design. The first phase has involved the use of GIS to visualise data relating to lead contamination and potential child population exposure. The second phase will explore the value of these maps in decision making in public health. A range of multiple, disparate datasets have been combined to produce novel overlays. This is the first time that environmental, demographic and historical data have been presented together to visualise the broad ranging aspects of the issue of childhood lead exposure. The study seeks to understand how GIS maps might be used for making sound, evidence-based decisions in public health. The potential for using GIS to facilitate inter-agency collaboration will be explored.

Design of the Study

A case study design has been adopted whereby multiple strands of data are examined in an attempt to understand the extent of the phenomenon in context. The first phase of the study has involved a desk based analysis of secondary data sources, using GIS. The second phase, in which we hope you will participate, involves interview discussions regarding the contribution of GIS to evidence-based public health policy.

Your involvement in the study

You have been selected to be invited to participate due to your experience and expertise as a key decision maker involved in contributing to public health policy decisions in the field of environmental health hazards. The study will involve participating in tape recorded interviews, either in person or by phone, which may last up to an hour. If you agree to participate I will arrange a suitable date and time for the interview, which can be outside office hours if this is more convenient. Prior to the interview you will be sent a brief report of the findings of the first phase of the study, which we can discuss further during the

interviews. Face to face or telephone interviews will not request personal information and will be conducted as expeditiously as possible.

Dissemination of findings

The principal research output of the study is the PhD thesis, but it is hoped that findings will be presented at conferences and in appropriate peer-reviewed journals. Anonymised findings, from the interviews, may also be discussed with the Newcastle Lead Task Force Group. Within the collaborative spirit, I am happy to supply you with a summary of the findings of the study on request.

Potential Benefits

There are no direct benefits to you from participating in the research but I hope that the research will help to facilitate understanding of the value of GIS in the evidence base for public health decision-making. Furthermore, there is potential to explore the use of GIS as a means to promote interagency collaboration.

Potential Risks

There are no explicit physical, emotional, social or legal risks involved when taking part in the study. Likewise, there are no potential safety implications associated with the research. The discussion of childhood lead exposure as a contemporary public health problem is a potentially contentious and politically sensitive issue. The study seeks to understand the contribution of GIS in decision-making processes rather than making judgements on policy and action relating to lead contamination.

Your rights

Participation in the study is entirely voluntary. You have the right to decline or withdraw from the study at any time.

Confidentiality and anonymity

Your anonymity will be preserved and you will be referred to in the study as a 'key decision maker' from your particular organisation. You will not be identified by name in the study. The data collected will be edited during transcription to ensure anonymity and interview transcripts will be confidential and as such stored securely at the University.

If you have any questions or concerns about the project I will be happy to discuss the project with you in further detail. It is possible, also, for you to speak with members of the study supervision team whose details are outlined below.

Supervision Team:

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Appendix IV: Consent Form

CONSENT FORM

Study Title:

Geographical information systems mapping and its potential to contribute to the evidence base for decision-making in public health. A case study of GIS representations of childhood lead exposure in Newcastle upon Tyne

I have read the information sheet and I understand the nature and purpose of the above study and I agree to take part.

I am willing to be interviewed and I understand that the interview will be audio-recorded.

I know that my name and details will be kept confidential and will not appear in any printed documents.

I understand that my participation is entirely voluntary. I can choose not to respond to particular questions and I am free to withdraw at any time, without stating a particular reason.

Name of Participant:.....

Signature: .....

Date: .....

Name of Researcher:.....

Signature:.....

Date:.....

Appendix V: Interview Prompts

Interview Prompts *(to be varied according to the participant)*

Overview of the session:

I will begin by asking you questions about the organisation you work for, your role within the organisation and the evidence you use in decision-making processes. We will then move on to discuss geographical information systems and the use or potential use of GIS within your organisation. With these thoughts in mind, I will ask you some specific questions on the maps presented in the report. We will finish the interview by asking you questions relating to the use of GIS as a vehicle to promote interagency collaboration.

Please describe your role in your organisation.

What do you see are the core values of your organisation in relation to the health of the public?

Can you say something about the way in which evidence contributes to decision-making in your organisation?

Is there a hierarchy of evidence for decision-making within your organisation? Do some data carry more weight than others?

Does your organisation regularly use GIS?

What do you think GIS offers/can offer to your organisation?

What is the status of GIS as a tool in your organisation?

What are your thoughts on the use of GIS as a source of evidence in decision-making processes?

What do you think are the limitations associated with the use of GIS?

Within the context of your organisation, can you think of any examples of problems that could be well suited to analysis with GIS?

What is your interpretation of the data presented in the report?

What further data do you think might strengthen the evidence base in relation to the issue of childhood lead exposure? *(Adapt for agencies with no explicit interest in child health issues)*

Do you collaborate with other organisations to influence policy? Can you give any examples?

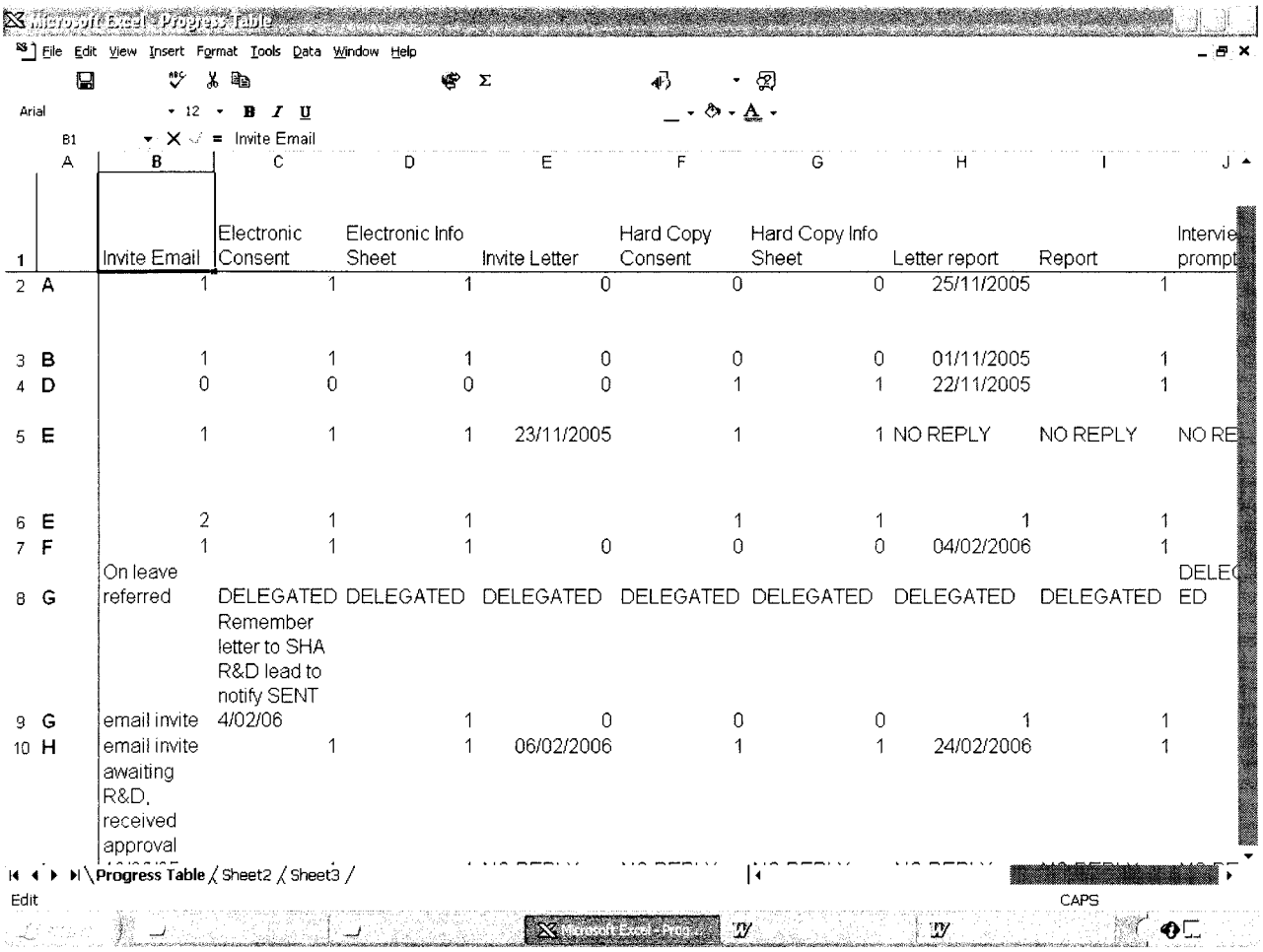
Do you perceive there to be any barriers to communication and cross-talk between agencies? If so what are they?

Do you believe there is mileage in the idea of using GIS as a means to promote joined up thinking between agencies?

Would it be possible for me to contact you in the future?

Would you like to receive a copy of the study findings?

Appendix VI: Study database



	A	Invite Email	Electronic Consent	Electronic Info Sheet	Invite Letter	Hard Copy Consent	Hard Copy Info Sheet	Letter report	Report	Intervie prompt
1										
2	A	1	1	1	0	0	0	25/11/2005	1	
3	B	1	1	1	0	0	0	01/11/2005	1	
4	D	0	0	0	0	1	1	22/11/2005	1	
5	E	1	1	1	23/11/2005	1	1	NO REPLY	NO REPLY	NO RE
6	E	2	1	1		1	1	1	1	
7	F	1	1	1	0	0	0	04/02/2006	1	
8	G	On leave referred	DELEGATED Remember letter to SHA R&D lead to notify SENT	DELEGATED	DELEGATED	DELEGATED	DELEGATED	DELEGATED	DELEGATED	DELEG ED
9	G	email invite	4/02/06	1	0	0	0	1	1	
10	H	email invite awaiting R&D, received approval	1	1	06/02/2006	1	1	24/02/2006	1	

Appendix VII: Sample Transcript

KJ So just to give me a little bit of background, to kind of guide the questions, could you tell me about your role at Gateshead PCT please?

Well I'm a consultant in public health medicine, so that's a very broad general role and I'm responsible theoretically for three areas, which would be health protection, health improvement and service quality improvement.

KJ Okay right.

But in actual fact I don't do an awful lot on health protection so I'm very much split between the latter two areas. So in terms of health improvement it's anything to do with the Choosing Health agenda currently

KJ Right, sure yes.

And service quality is to do with commissioning, often rationing and poorly performing practitioners a lot as well.

KJ Right so it's quite a broad role

A broad role exactly

KJ So from your experiences, this is quite a broad question I'm afraid. Can you say a little about evidence-based decision-making? How you use evidence in your day to day practice?

Well currently I'd say the only place we strongly use a lot of evidence for decision-making would be in relation to rationing.

KJ Rationing of services?

So there we will use the evidence and hunt for the evidence and take the time to read and consider the evidence. But to be very frank I think that's the only time.

KJ Right, sure so it's mainly the services, the rationing.

Yes

KJ Have you at any time used GIS evidence?

I haven't, well I've used maps and GIS briefly touched on as a technique on my MSc so that's years ago but then also I worked at the University in the academic epidemiology public health department. And I was involved in a lot of research around primary biliary sclerosis, which is a very rare liver disease and nobody knows what causes it. We were trying to do a case control study and cohort study, so lots of study, and there's a perception or evidence, some evidence that shows that it's much more common in North East England. But whether that is true or apparent we don't really know because we haven't really hunted for it. And one of the theories was that it

could be related to the water supply and there was a sense that maybe we should be mapping where the cases are to get a feel for clusters of disease for an environmental cause.

KJ Really interesting.

We didn't actually do it. But that was the theory. There just wasn't enough time.

KJ That's the thing isn't it

But that would have been an idea because we had all the postcodes for each of the cases.

KJ So the data were there?

Oh yeah. We had hundreds no thousands of cases, we had 1200 cases of this rare disease over time as well so we had time trends and it was all within the North East, you know a tightly defined boundary as well.

KJ That would have been really suited to GIS, looking at that spatial dimension. Interesting. You talked about part of your role being in service quality and commissioning services, have you come across, well do you use GIS in that way at all?

I don't know whether it's strictly GIS but...

KJ Mapping I suppose?

Mapping in terms of, we talked about mapping exercises where we're trying to find out what's going on and mapping what's going on to what people need. But in reality it's very much about portraying the data that we have and it's routine data usually to show deprivation in different wards, it's all ward based, small area statistics about deprivation and perhaps about mortality rates, smoking rates so it's around health improvement.

KJ But you use actual physical maps?

Yes maps and the colour and the boundaries, yes.

KJ And the IMD?

But very much to demonstrate rather than investigate.

KJ Yes, so quite descriptive?

Yes

KJ That's something I've been thinking about looking through the literature that people use the term mapping in so many different senses.

Yes

KJ So they can use it to talk about brainstorming, you know mapping.

Yes and it's a very common term but they don't actually do "it".

KJ They don't actually link it to a map at all.

Exactly

KJ That's interesting. So the way I've kind of structured the questions is to talk about GIS technology itself.

Mmhmm

KJ And then to move on to your feelings about maps and maps as evidence is that's okay.

Okay

KJ So how do you as an individual and as a public health consultant value GIS as a technology?

GIS versus maps?

KJ GIS, the kind of computer packages. How much do you use it in the PCT?

I would say at the coalface, it's underused and it's probably of limited value to be honest and that's very much a modern day phenomenon. I've been in public health since 1990 and up until 97 things were getting quite sophisticated and we were probably getting into a position where a GIS would be very valuable but the reorganisation diluted all of the management and expertise within PCTs so you end up with a work force which really weren't experienced in anything technical and very much under day to day pressures so it has very limited value. In using a computer technology there isn't enough money around to pay somebody who would be skilled enough to do that job properly.

KJ Right.

And the other side of the coin is nor would there be sufficient people around a table with the skills to actually understand what's been done. It's almost too sophisticated for the state of the current National Health. That's my concern. Now a straightforward map that I've talked about that's not but GIS is too sophisticated.

KJ The analysis and modelling and such like.

The sophistication of it: it's quite technical, it's very numerate and a lot of people in health aren't that numerate.

KJ So it might just put people off immediately?

Yes

KJ they wouldn't engage with it?

Exactly

KJ So would it be fair to say that it doesn't really have much status in the PCT?

Unfortunately, I think that's a shame and I think it's just a symptom of the way management and health service management is at the moment. Health services research that's fairly under developed too.

KJ So it's more the resources not being there?

Yes exactly, the culture. There's a culture of, research used to be very valued, pilot studies were valued, audit all of these things were valued and now.... And expertise, technical expertise was valued and the current culture is very much about generic skills, everybody being able to do a bit and inclusiveness. Once you get inclusiveness something like GIS isn't there.

KJ It doesn't fit in?

It doesn't sit in that.

KJ That's very useful. So are there any projects that you know of at the moment at the PCT where GIS is being used or is it being used at all for any visualisation of data?

Maps are being used.

KJ So it's being used at a simple level?

At a simple descriptive level yes but anything more sophisticated I don't know of anything at the PCT. I suspect at the University, someone like QQ she's doing it.

KJ Yes QQ has been instrumental in the project, with it being lead.

Yes she would but not in the PCT.

KJ I've spoken to people at the Local Authority and they seem to have more people interested in it and have the resources to develop it and more in the environmental side, contaminated land and such like.

I mean we've had some contamination incidents in Gateshead but again it's so unsophisticated that I don't really see the advantage of getting into the technical side of things.

KJ So it would be a case of weighing up well is whether the effort going to be worth it?

Yes. In some local authorities I think there's a lot more development around the technical side than others. I think in general there is a lot more money around and they're very attracted to the idea of having all of that technology. I think they find it very attractive but I would still challenge whether they would be using it effectively that would be my perception at a grass roots level, of local authority environmental health officers.

KJ Using it effectively? So there may be, do you think, an issue of misusing their outputs or just using it at quite a simplistic level?

I think they would like to have it and show that they use it, well show that they've got access to it and they've looked into it. But whether they would actually use it actively that would be my concern. They do a lot of things like Participatory Appraisal Technique, they're into research, they like to show that they've done research but then actually the stage when you implement the findings that's where they don't deliver.

KJ Right so it doesn't filter down into practice?

That's my external perspective

KJ Interesting. That's really useful. So in your experience have you come across any projects outside of the PCT, at conferences or whatever or something you've heard about at universities, where you've seen the use of GIS and to you it's been valuable?

If there has been it's always been around environmental issues.

KJ Yes

I can't remember the term but a while ago there was a lot of farmers having problems with...it was a consequence of one of the chemicals they'd used and GIS had been useful for that. Certainly things like lead, anything to do with water, outbreaks of water based infection it would be useful then. So mainly contamination and also leukaemia, childhood leukaemia, clusters around well obviously radioactive places but also the electric masts

KJ Pylons?

Yes that sort of thing, power stations, electricity masts that sort of thing.

KJ That does suit GIS. You can see, just intuitively, the value of it can't you?

Yes so they are the main things that spring to mind.

KJ That's useful. So in your mind what would you say were the benefits of using GIS?

Well it appears to me to be a great way of juggling, for want of a better word, lots of different datasets and making sense, painting a picture, a bit like epidemiology where you actually create patterns out of data. And the patterns can lead onto new, meaningful interpretations and conclusions.

KJ I think that's a really interesting way of putting it: juggling, juggling different datasets because for me that's one of the key benefits that you can bring together these different strands, data that haven't been seen together before and overlay them. I think that's quite a useful thing to be able to do.

Yes and the only other techniques that are able to do that are very complex statistical things, which aren't very accessible to many people certainly not. So it's much easier and accessible to more people.

KJ And do you think that's because it has this visual component?

Yes very much so. Anybody, well not necessarily anybody can read a map, I've found that it can be tricky but there is a perception that maps, we've grown up with maps, they're childhood things, jigsaws are childhood things, traditionally it's not a challenging or threatening skill. Something like a statistics correlation co-efficient is immediately a turn off.

KJ Yes, I can see that – that's a very good way of describing it. So accessibility?

Yes. I think that culturally we are, as a society, used to maps.

KJ It's something people use.

We see a weather map every night on the TV but they don't give us the statistical probability, they don't say that, about it being cloudy the next day.

KJ That's true. So it's something people can relate to?

Very much so.

KJ Because they see it on a daily basis.

Yes

KJ So moving on from that what do you feel are the limitations of using GIS?

Well it relies on having datasets. And that's the problem. There's a limited number of useful datasets around. So to be useful in itself you've got

to have high quality datasets. So they have to be timely, reliable, repeatable, complete all of those criteria. And there are very few like that. There's the routine ones, which are restricted, in terms of purely things like births and deaths, ONS data. Or it means going out and collecting special studies and they're expensive and you get a snapshot in time. So it's a great idea but difficult to sustain in the long term.

KJ Sure. So it's the availability and if the data are available are they good quality?

Are they postcode data because there's a whole issue around, I can't think of the right word, but personal information.

KJ Identifiers?

Yes identifying people so something useful might be around sudden infant death syndrome where there's an environmental thing around power stations but that's such small numbers and they don't want to postcode that.

KJ So it's a sensitive issue?

Or mental health issues.

KJ Teenage pregnancies?

Yes there's some tricky things sometimes.

KJ And when it's small number as well?

It's alright when it's huge numbers, it's routine data but yeah. I suppose if there's a public good out of it, like an environmental hazard then that makes it more acceptable.

KJ If people can see the benefits?

Yes, exactly.

KJ Yes it all gets quite complex and I think the data quality issue, it resonates with me because I started off wanting to do this grand mapping project, pulling together secondary data on childhood lead exposure.

Right.

KJ So we've got lead in water and soil, in old housing...

Yes

KJ But the data just weren't there, they just aren't available. So you have to make compromises and make best use of what you've got. And what you end up with is not really a fair picture at all, you can't really look at what you

were wanting to look at in the first place. I found it was a series of compromises because I think Newcastle University was wanting me to go down the geostatistical route of modelling the water and soil data to produce like a composite score for different points of lead.

Yes

KJ But it just wasn't feasible because the data they weren't timely, they weren't reliable, they weren't...

Exactly

KJ The methods through which they were gathered weren't, you know

It's discipline all the time with the methodology for a dataset

KJ Yeah. And that's okay for a PhD when you've got the time

Yes it is. But when PCTs are wanting to invest money when they've got scare amounts

KJ Exactly.

And all of the datasets that are developing in terms of health are things like hospital activity data, off the top of my head I can't think of a good reason why we'd ever want to use GIS for that.

KJ It just doesn't make sense I suppose.

I mean we look at rates of usage in terms of whether there is an inequality, some people get more exposure to certain operations than others. But, that's easier statistically for me.

KJ There are some things which just aren't suited. There needs to be that kind of spatial dimension that is important.

Hmmmm

KJ Interesting, so moving onto maps, GIS representations, erm do you think that GIS is a valid means of presenting data?

Can you tell me what you mean by that?

KJ Well rather than presenting it in a table

Or a bar chart?

KJ Or a pie chart do you think a map is a valid way?

Yes, very much so. Yes.

KJ Do you feel that GIS data can fit into the hierarchy of evidence, where you've got the randomised controlled trial at one end and the anecdote at the other end?

Hmmmm well yes because it's part of descriptive evidence so yes very much so.

KJ Where would you place it?

I'd stick it, it's definitely part of an analytic tool potentially so higher than just a cross-sectional survey but it's lower than a case control study because you can't you can't get the causal or the evidence of causality.

KJ Yes

Thinking about all of the criteria. So...but it is more powerful than purely descriptive because you are able to get a correlation from that. It's that causality chain so it's near the bottom for that reason.

KJ Now that's interesting. Thank you. So we spoke about the technology, GIS itself, the system, but maps, maps for communication and presentation. What do you think are the advantages of doing that?

I do think that's really, really useful because of all sorts of things. Like I was saying before culturally maps are acceptable so people are used to dealing with maps. Maps are interesting because they're usually colourful and they're different shapes so they hold people's attentions. Again it's away form the graph thing which is very much about school and numbers which turns people off.

KJ Yes

Maps are shapes and colours which even primary school children can relate to. So they're much more accessible to a multi-disciplinary, multi-agency audience. And also we've done a lot about communication in the PCT because we recognise the need to engage with so many different people with lots of different backgrounds and knowledges so in themselves they *(the maps)* are a metaphor for spatial differences so you don't even have to explain them. So with a, say if you comparing standardised mortality rates between areas in a table you almost have to explain that's what you're doing. But with the map you've got a metaphor already that message that says what you're doing.

KJ So it's almost self-explanatory?

It's self-explanatory and individuals themselves, a good proportion of the population see the world or interpret the world in a visual way. So for those people maps are excellent and even for the people who are the kind of feeling people out there who experience in a feeling way they can actually get

a grip, touch maps and relate to them themselves as well so it's a relational thing for them as individuals in a way that they can't see themselves in a table they can certainly see where they live or where somebody they might have ever met or seen lives.

KJ Absolutely so it feels real, it feels tangible?

Exactly.

KJ That's a really interesting point. It's amazing how so many different strands have come out of the interviews.

By interviewing different people.

KJ It's been so valuable. So following on from the advantages, anything about the disadvantages or limitations of maps as evidence?

Well it does appear to over-simplify things. It's hard to show confidence intervals on maps.

KJ Yes absolutely.

I do think that people aren't able to do the multi-layered stuff so they just do two 'axes'.

KJ Yes

And so really you're restricted to things that are geographical. Then the artificial boundaries, the way that you carve up your map and traditionally we do it by wards. But when you're looking at environmental things in fact they're completely meaningless aren't they?

KJ Absolutely.

So actually it would be better to have hills or dales or rivers or whatever something relevant.

KJ Around natural communities?

Or communities yes. Communities, housing estates would be better.

But the wards we do use well they're also so changeable.
And general practices I still can't quite see the use.

KJ I think that's something that you can do with GIS – you can change the boundaries that you use.

Yes that is an advantage.

KJ So would you agree or disagree with the following statement: maps are powerful strands of evidence in public health discourse?

I would disagree with that one.

KJ Why would you disagree with that?

I think they're powerful tools in public health discourse but as evidence I think that was just a bit too strong.

KJ So it's a tool in the hierarchy of evidence.

They're not the evidence are they? It's the data that goes in. They're just a tool. Well they can be an analytical tool but in terms of discourse they're a presentation tool.

KJ A tool rather than actual evidence *per se*. Would you like to say something about, we mentioned colour and how people can relate to colourful pretty pictures. Would you like to say something about the use of colour in map making?

Yes well colours are really popular in the NHS at the minute. Everything is colour coded on a traffic light system but I haven't actually seen the traffic lights used in mapping and yet it's so obvious that you have your red district. They usually have shades of blue for Gateshead and the darkness or the lightness reflects deprivation but really it should just be a traffic light system.

KJ Traffic lights for good and bad?

Yes for alert areas and okayish areas 'cause that's quite intuitive again isn't it? It could be quite confusing if different people producing the maps use different colours. And again colour's great but the reality is they're photocopied for a meeting and they all turn grey and you can't read them.

KJ And you can't discriminate?

Exactly.

KJ Yes. That's a good practical issue. We mentioned, we talked about data quality issues, about the timeliness of data, the reliability etcetera. So we've spoken about that. As a public health consultant how often do you see reports with GIS representations in them, with maps?

With maps in probably, do you mean PCT based reports or reports in general.

KJ In general.

Probably once a month.

KJ Right

It depends what I'm doing.

KJ And would that be reports that were using maps in a descriptive way rather than...?

A descriptive way yes usually to show currently it would be around inequalities. So different smoking rates different obesity rates or even different hospital admission rates.

KJ Mmmm so is it quite rare that you see a report where GIS has been used for analysis?

I don't think I've ever seen one (*laughing*)

KJ Right.

If that's rare enough! And that's in sixteen years in public health.

KJ Wow. So in what instances, you mentioned a little bit about the environmental and contamination sort of problems but are there any other instances where you might use GIS instead of traditional epidemiology?

I'm sure there must be...I suppose you could do it again around communities and housing, for housing I think. You could see if you've got higher TB rates in certain housing estates or local authorities.

KJ That would be useful, infectious disease, which has housing, environmental dimensions.

And certainly legionnaires disease...Cooling towers. But we're back to the environmental. So hazards. I'm trying to think of things in terms of host agent environment. So the environment thing, the hazards, the agents so you could certainly do it if you had a chemical contamination incident to follow it up. But whether it would be quick enough.

KJ Yes that's the thing isn't it collecting the data and having the maps available

And with the host thing, we move around don't we so it would have to be something to do with houses, schools, organisations. I still can't quite see what the value would be.

KJ When you've got other alternatives that may be more rapid or cheap or....

It may be there it's just I haven't come across it and I haven't given it enough thought myself. I'm not saying it would never happen.

KJ The TB example is a good one, with the poor housing

Or maybe asthma. So it wouldn't have to be an infection, in a different sort of environment the home environment. You could do kind of things like childhood obesity and proximity to certain shops.

KJ Right fast food outlets?

Or shopping centres so there is...that would be quite interesting.

KJ Yes, food deserts?

Yes all of that healthy eating, the food co-ops all of that.

KJ Yes access.

And there is something around and we don't do it very well and we haven't yet so maybe GIS is the answer about stacking up the whole thing around wealth in terms of education and income.

KJ So like a composite thing?

Like a composite because what we don't know, we know that all of those things influence health but what we don't know is which is most important. And GIS you could probably help come up with that answer.

KJ Perhaps with the use of the overlay function? Interesting.

So that's possibly one route to get to those answers because I can't see another way of getting those answers.

KJ Bringing those together.

Yes.

KJ So moving on slightly I've been thinking about sort of the dangers of using GIS if somebody was to take some data and use GIS erroneously. Have you come across any instances of that?

I have a limited amount of experience. I think this project I originally said about the University and these cases of primary biliary sclerosis and we were trying to map the clusters and relate it to water supply but my concern all along was that we didn't know they were true clusters. I didn't know whether there was a complete dataset and whether it was about case identification.

KJ So they may have been misdiagnosed?

Yes. Again it's back to... I suppose when I was at the university there was a lot of interest in GIS but it's back to that business where the person who

does the GIS doesn't necessarily understand the dataset given to them. So they could do really fancy stuff but I never really sensed that they fully understood the dataset or the person that gave them the dataset fully understood.

KJ So it was that kind of gap.

Yes there was a gap in terms of the partnership between the GIS expert and the dataset expert.

KJ That's a really interesting point because yes you can produce these very pretty maps but whether they actually mean anything.

Yes and the map producer will never know at all and will actually be very proud of what they've done and think it's fantastic.

KJ Absolutely

And because they're so accessible the press or local authority will love that and the local authority people will never think to ask, they actually don't get into the thing about the whole quality of the datasets.

KJ They don't question anything?

But that's a very general thing, police experts, the ones that collect the data do but a basic environmental health officer won't get into that.

KJ And the media could jump on it?

The media would jump on it because maps are media friendly.

KJ That's something that I felt quite concerned about when I was trying to pull together my data 'cause as I say I didn't have the data that I wanted because they just weren't there.

Yes

KJ I wanted to look at the possible association between lead and low birth weight.

Oh right

KJ And I was able to collect some data from the RMSO but because I didn't have I only had you know a certain number I just felt that the map could really be quite contentious 'cause it was implying this association that may not have been there at all.

Yes.

KJ And you don't have the power to put confidence intervals on as you say. I felt in a way almost like I was misleading people although I said I'm not looking at causality. I made that clear. But without reading, if people were just to look at a picture they could say oh look at that brown area where there's lots of lead oooh there's lots of low birth weights.

We could say oh well let's do a causality study but the public aren't going to say that and nobody who doesn't understand causality would do that. Look at what happened with MMR.

KJ Exactly, exactly and people still aren't....

And that's, I suppose it's like a double edged sword because they're so accessible and yet there's that's a danger of them.

KJ Yes a double edged sword that's a good way of describing it because yes you want people to engage with them but you don't want them to take away the wrong message.

Or jump to the wrong conclusions.

KJ Yes...yeah. Can you think of any examples that kind of parallel that? Anything that you've come across?

Where people have come to the wrong conclusions?

KJ Mmmm

Well it is often geographically showing differences in say something like a high death rate. You would get, if you did Corbridge, a really high death rate round the doctors surgery.

KJ Yes, absolutely because there's lots of old people.

Because is it Charlotte Straker there?

KJ Charlotte Straker yeah.

And the residents there because there's been a new build would say that it was something to do with the building work and the wracks that came out oh I don't know what they'd say but it would really cause a media storm or a lot of interest whatever.

KJ Absolutely.

But it could be completely meaningless and that's a very common, it's the whole thing about are differences real or apparent, the whole theory about how do you actually prove whether it is real. And so it's confounding isn't it and bias?

KJ Sure. That's really been a concern of mine because it's a responsibility really because maps, statistics can lie but I think maps can as well.

Exactly

KJ So have you ever been in an audience at a conference or something where people have presented data, GIS data and the audience has misunderstood it or misinterpreted it?

I haven't had that experience, I haven't seen it presented so.

KJ That's fine. In a similar vein do you know of any instances where GIS has been poorly received or the value of data has been doubted?

I think any situation that is highly politically charged like the leukaemia clusters and power stations for example some people because of the sensitivities don't accept the evidence or doubt it's power because it isn't demonstrating what they want it to show.

KJ So moving on to the idea of GIS and data sharing to promote interagency working. Have you come across any examples where GIS has been used effectively to share information?

Oh gosh.....I've got a distant memory of child accident prevention where we were trying to use data from the police service and NHS datasets as well but I don't have a visual image of how far that got. I know somebody called AA down in Middlesborough?

KJ Yes I've come across him.

He's really into this sort of thing and he's got this idea of having a kind of desk top driving station where you press a button to pull up local authority datasets, police datasets, NHS. But what he hasn't gone into is then the mapping stage of how you actually integrate all of those separate things. So I suppose the answer is no – that's the long winded no, I 'm thinking out loud!

KJ No but you've had an experience where people have been trying to collaborate and work together.

We try to do that, very much so, it's definitely around accident prevention. There was something else around drug and alcohol misuse as well. How do you actually get a real feel for how many users are out there and that would take some quite complex stock. We're actually looking at a different technique, analytical epidemiology and see how the cases they get each time, I can't remember the term for it. I don't think that relates to GIS.

KJ That's an example of partnership working.

Yes.

KJ So would you feel that there is mileage in this idea? Peter Kelly's idea? It would bring together these multiple, disparate datasets to share information?

I do. I think somewhere that would be appropriate to lead on something like that would be the Public Health Observatories.

KJ Yes

Then you've got a critical mass of expertise, so you've got a critical mass of people who actually understand the data, have the data and can actually use the data and interpret it. And they, 'cause I really don't feel that PCTs and certainly the way the NHS is going it's too expensive.

KJ Absolutely

And it's the skills that are expensive rather than the technology I think.

KJ And to have that kind of ability to be involved in all stages to get the coherence.

Yes it's certainly something that the PHO could do very well.

KJ Definitely....What do you feel would be the major barriers to the collaboration approach, in trying to bring these different groups together to share information?

Well I do think there is a will to share information. The main barrier is the communications skills. The people, who are researchers and have the technical skills, data analysts and manipulators - as a gross generalisation - don't tend to be into the politics of communication. And once you're into partnership working it's a lot about politics, communication and patience and understanding power and different agendas.

KJ It's a complex scenario.

And that is just completely different to trying to do what you're doing in an abstract, theoretical unit sense. So that's a big barrier. The reality, pragmatic versus theoretical. So theoretically it's great.

KJ So it's great in theory but whether it would work in practice?

And this child accident prevention thing I said we all had the right ideas and there was a will to share but then actually making it happen. And often the will and the willingness, the ideas often come from quite a senior, strategic level so the representatives that go to multi-agency groups tend to be senior managers, directors whereas the people that are actually at the front line with the data have a different job altogether and so they're not party to the discussions. It's something about the way the work is shared out, roles and responsibilities.

KJ There's that disjointedness?

Yes. So that's within organisations.

KJ So you have that problem and it's compounded.

You've got that problem and it's compounded as soon as you go between organisations. I mean there's obviously an issue nationally isn't there with probation and the police – there's something not working there.

KJ Yes the shared aim is there but the practical…

I mean I was doing some work on specialist commissioning and I wanted to compare data from three hospitals that were doing spinal surgery, so it was very specialist surgery and I needed three different datasets and had to liaise with three different hospitals and it was a nightmare. And that so that was just one agency, three different units but one agency. And again they wouldn't give me the datasets they said they would do the analysis for me and so I never got the analysis that I really wanted and I couldn't play with the data as well which is part of the process.

KJ Absolutely and was that all to do with patient confidentiality?

And power and yeah, information is definitely a power thing. It's one of those resources that make organisations powerful and people within organisations powerful. So people use it as a negative power thing.

KJ A bargaining tool?

Yes the whole of that it's all politics isn't it?

KJ So this whole idea of collaboration it just becomes….?

Well it's a trust thing isn't it? I'm saying all the time oh well people don't understand the datasets and if I'm saying that about the health service datasets the police will be saying about theirs and they certainly wouldn't want a health person coming along and taking their dataset.

KJ You are to some extent precious about your own data I think it's natural

Yes very much so, yes. And in terms of health service data it's actually really complicated, definitions of the hospital activity codes for example and so you really need to be an health information expert but just because you're a health information expert wouldn't make you a police information expert at all.

KJ Exactly

And it's an acquired knowledge, it's not just a degree it's actually an acquired experience and expertise. It's not readily transferable.

KJ Do you think there's an issue with kind of closed languages, using different codes.

Definitely yes all of the different definitions and the limitations of the definitions. And I think another barrier is that, I'm the same here about the police data, I obviously have very high expectations that they've got fantastic data and it's complete and all of that sort of stuff. But again they got frustrated with us in health that when we gave them our data that we had more than we did. They thought that we had all of these accident rates but we only have the deaths really.

KJ Right

Or admissions with fractures and more serious injuries. But the child who is knocked over, concussed and gets discharged within in a day we don't know about that. We only know if they've had surgery. So they have expectations, so it's not just understandings it's expectations. And assumptions.

KJ Assumptions definitely. It makes the whole process more complex, more difficult.

Yes it creates more boundaries.

KJ That's very useful stuff. Ehm, a more abstract question really to finish with. We talked about the concept of mapping and mapping being ubiquitous in public health but would you say the term mapping what does that term mean to you?

It means matching

KJ Matching, that's great, thank you. That's brilliant I will stop now.

Appendix VIII: Contact Summary Sheets

Contact:
Organisation: ---
Address: ---
Date of interview: Monday 20th March 2006
Time of interview: 11.00am – 12.00noon

What were the main issues or themes that struck you during the interview?
Interest in use of GIS for analytic purposes.
Placed emphasis on quantitative data and the use of GIS within traditional epidemiology.
Clear understanding of the importance of time and place in public health issues – recognised the opportunity to employ GIS effectively

Summarize the information you got or failed to get on each of the target questions.

Decision-making in organisation:
Difference between data and information.
Two types of evidence – info on what's going on and info on what works in practice.
Value of GIS technology:
Shortcoming – need to improve data availability to increase use of GIS
Benefits of maps: Immediate, effective
Limitations of maps: dependency on high quality data

Thoughts and feelings regarding the encounter.

X had quite an intimidating presence and at times I struggled to hear what he was saying as he spoke very quickly. I did feel on edge during the interview and probably didn't probe into some of the answers enough but on the whole I was pleased with my conduct during the session. After the interview had taken place and the recording equipment was turned off a very strange thing happened. X questioned me as to why I was nervous. When I replied that I found interviewing public health elites quite a nerve-wracking experience he suggested that I shouldn't be nervous and perhaps I should get some acting coaching to boost my self confidence! He then also went on to ask if I had thyroid disease. X said that because I was thin and had quite staring eyes as well as a nervous disposition that I might want to get my bloods checked to rule out hyperthyroidism. He asked me to follow his pen to check for lag lid and then even took my pulse. I felt this was a little inappropriate given the situation and in a way I think it may have undermined my confidence further as I thought I had come across okay in the interview. Aside from this odd experience the interview itself went off well and some interesting themes/ideas emerged. X is obviously a highly perceptive man and some of his answers took on a more philosophical slant compared with other respondents. For example, he highlighted the importance of the central tenets of time and place inherent in public health whereas other participants may have alluded to these notions but because they were assumed to be obvious they didn't explore these ideas in depth.
I feel that there was a power struggle and X's urge to make a diagnosis was indicative of a need to take back control of the situation and to revert to being a questioner rather than a respondent to regain the dominant role. Perhaps also

by drawing on his medical knowledge and expertise he was reaffirming his status as a "medical man" and doctors of whatever type are highly respected and occupy high status in contemporary western society.

Any other salient, interesting, illuminating or important points?

X's thoughts on why GIS is not used more in the HPA resonated with my reasons for not taking the GIS analyses further, that is GIS needs good quality data otherwise the outputs are rubbish.

What new (or remaining) target questions do you have in considering the next interview?

Explore notions of time and place with respect to the use of GIS in public health

Contact:
Organisation: ---
Address: ---
Date of interview: Tuesday 21st February 2006
Time of interview: 15.00 – 16.40

What were the main issues or themes that struck you during the interview?

The interviewee has been aware of GIS for some time but had no experience of using it, the interview therefore was focussed on the use of maps as evidence in the public health context and questions relating to the technologies themselves were bypassed. Acknowledged that the organisation may not use GIS to its full potential.

Summarize the information you got or failed to get on each of the target questions.

Question	Information
Decision-making in organisation	Sees GIS at the "harder" end of the hierarchy of evidence but that's dependent on how it is used.
Value of GIS technology	Could be used more. No direct experience of using GIS or using maps as evidence herself but is familiar with map presentations in conferences and meetings and commented more on those.
Benefits of maps	Produces striking overlays. Good way of illustrating points and emotive issues.
Limitations of maps or	Possibly dangerous, can imply the wrong messages for example with causality. Need to understand the degree of risk uncertainty involved.

Thoughts and feelings regarding the encounter.

The interviewee was most helpful and encouraging. She asked about my career aspirations and gave advice about working in public health, which she described as an "*impenetrable*" world. The interviewee was honest and open, rather than conducting the interview where both interviewer and respondent were opposite one another behind a desk we sat side by side. Body language was open and non-defensive.

Any other salient, interesting, illuminating or important points?

Articulates limitations of GIS by comparing it to a satellite navigation system and describing its shortcomings with respect to the analogous functions of both technologies.

An informal straw poll with individuals in the planning department showed that although GIS technologies were present (and had been for 2 and a half years) they were not being used as nobody was trained to do so. Licensing issues and cost were also highlighted as prohibitive factors in making GIS more mainstream.

What new (or remaining) target questions do you have in considering the next interview?

Speak with someone regarding the Community Profiling Project due to be published at the end of March.
Explore the construct of mapping – what does mapping mean to you?

Contact:
Organisation: ---
Address: ---
Date of interview: Friday 24th February 2006
Time of interview: 10.00 – 11.00

What were the main issues or themes that struck you during the interview?

The discussion covered new ground and issues relating to GIS were compared with other methodological approaches in the public health practitioner's toolbox. In most of the respondent's answers he compared GIS to traditional epidemiology. This was the first time an interviewee had adopted a comparative strategy to questions. Examples of GIS.

Summarize the information you got or failed to get on each of the target questions.

Question	Information
Decision-making in organisation	Possible
Value of GIS technology	Could be used more. Useful mostly in analysis rather than presentation.
Benefits of maps	Immediate can talk to different sections of an audience using one map.
Limitations of maps	

Thoughts and feelings regarding the encounter.

The respondent was thoughtful, relaxed and open. Despite being so high profile with vast responsibilities he was happy to talk with me on a range of issues.

Any other salient, interesting, illuminating or important points?

Traditional epidemiological methods are not the panacea, like GIS they too have limitations. The respondent didn't see much value in the use of GIS to foster interagency collaboration. I encountered some difficulties when trying to describe the ideal of an accessible GIS database holding diverse information supplied by a range of agencies to allow tailor made maps to be produced using a generic software. Once the idea was communicated properly the respondent was more positive towards the suggestion.

What new (or remaining) target questions do you have in considering the next interview?

Interview someone at the NEPHO who will have been involved with reports produced recently that may have mapping potential.
Perhaps speak with a geographer.
Ask PH practitioners in what instances they might use GIS instead of traditional epidemiological methods.

Ask about the interface between academia and public health, dissemination etc. Question whether decision-makers see PH reports which feature GIS at all.

Appendix IX: Extracts from Research Diary

May 2004

I met with someone from the local authority today to discuss access to the historical maps. The LA are happy for me to come in two or three times a week to conduct a historical survey of sites associated with lead contamination. Sites of former Lead Works in Newcastle:

- *Elswick (Calder's – recently closed in the past few months, land to be capped for redevelopment, St Anthony's Lead Works?);*
- *Walker;*
- *Two sites in the Ouseburn area – one has been remediated (Byker Farm), the other is now a land fill site, there was also a paintworks in the Ouseburn area;*
- *Gallowgate (Loch Blackett, site of former bus station now being developed into offices and flats).*

June 2004

The health inequalities agenda resonates when interpreting the data. The issue of lead exposure is a compounding factor on children who may have pre-existing nutritional deficiencies and whose health may already be poor. In more affluent areas where lead levels are high (e.g. Jesmond – near to the Ouseburn - centre for industrialisation in the 19th C) favourable social and economic factors may have a buffering effect on a child's susceptibility to lead.

September 2004

Due to the limit of variables that can be displayed on a single map additional information is required for judicious map interpretation. Though it is well recognised that association does not always imply causality I feel wary of mapping together two possibly contentious variables. While the audience I aim to present to is well educated and familiar with the tenets of basic epidemiology, I still feel that there is a risk of misinterpretation, especially in view of the immediate impact of a map and the possibility that a qualifier, caveat or explanatory note might be overlooked. The responsibility of producing judicious maps is ever present in my mind. There is a pressure, probably more internally than externally, to comply with the scientific and ethical code that the academic research environment commands.

March 2005

Can GIS permeate into new disciplines not traditionally associated with geographical methods? The theme of disseminating GIS reflects one of the core, central themes of the study: collaboration. Explanatory example: computers were specific to the IT community but they are now ubiquitous and essential to communication.

August 2005

The order of interviews is an important consideration. Should the order reflect the environment/health dichotomy or the power continuum or should it be arbitrary?

September 2005

Shelley Lanser has agreed to act as mediator to introduce the PhD study to possible interviewees. Shelley will email participants and inform them about the links with the Lead Task Force Group which hopefully will increase my credibility as a researcher. Snowball sampling could be used if there is a

reluctance amongst organisations to participate. The option of interviewing a member of staff from middle or lower management rather than senior management could be offered to decision-makers with massive time pressures.

December 2005
My first interview. I tried to put the participant at ease by making small talk. The participant asked if he was the first person to be interviewed. He appeared quite defensive to the point of being hostile, condescending and abrupt. Perhaps the defensiveness arose due to the subject of the case example, a contentious issue. Or maybe it came from his reaction to me as a young, female researcher. (Consult literature on interviewing elites and the dynamics in the relationship between a young, female interviewer and an older, male interviewee, the balance of power). Am I being oversensitive or is it simply a result of my inexperience at qualitative data collection? The experience has made me doubt myself and question the validity and usefulness of the project. Do I really have it in me to do this?

December 2005
The respondent was friendly, open and helpful. She seemed genuinely interested in the project. Maybe I was more relaxed as this wasn't my first interview. Perhaps I just felt more at ease and confident as the interviewee was female. I wonder if speaking to the respondent prior to the interview helped to create rapport? It may be worthwhile telephoning other possible participants to arrange the interview rather than communicating by email alone as was the case in the first interview.

May 2006
What is the glue linking phase I and phase II? The mapping report is common to both phases but it still feels like a linear progression, which conflicts with the complexity agenda. There are difficulties in bringing together the quantitative and qualitative phases with opposing realities. The study is a challenge to the paradigm norms it is boundary spanning, examining how we work in collaboration, dipping into other people way of seeing the world and breaking away from silo working. The study could offer a new(ish) model for decision-making in public health.

December 2006
The thesis draft feels disjointed - too descriptive and lacking analytical clout. Complexity theory is emerging as a suitable framework for both holding and accounting for all parts of the thesis: public health is complex, decision-making is complex, GIS is complex, the data sources for mapping were complex (incomplete, out of date, inaccurate), therefore the process of bringing together each of these dimensions is naturally going to be complex.

Appendix X: Letter of support from Health Protection Agency North East

Headed notepaper

Date

To whom it may concern,

As the Regional Environmental Epidemiologist for the Health Protection Agency (HPA) North East and Chair of the Newcastle Lead Task Force, I was asked by Northumbria University to be part of the supervision team to advise Kerry Joyce in her PhD study.

Addressing the issue of children's health and environmental hazards is a priority for the HPA and the heavy metal, lead, has been cited as a particular concern. In the past two decades there have been few epidemiological studies on the issue of childhood lead exposure in the United Kingdom. There are no recent data on child blood lead levels and there is also a gap in the evidence base relating to the distribution of lead throughout the social and physical environment.

The value of this project lies in pulling together available environmental data on lead in the soil and water in Newcastle upon Tyne, along with demographic data, to highlight potential population exposure. Phase II of the study involves interviews with stakeholders from a range of organisations relating to public health and will consider the value of GIS maps providing useful evidence for decision-making. Ideally, the interviews could highlight this issue to key staff involved in delivering the public health agenda. There is also potential to promote the idea of using GIS collaboratively to share information. Finding effective ways of clearly communicating and collaborating across a multiplicity of agencies is another challenge inherent in the approach to dealing with environmental hazards and potential health outcomes.

This project is supported by the Newcastle Lead Task Force Group, an interagency group involving members from Newcastle City Council; Northumbrian Water Ltd.; the Northumberland, Tyne and Wear Strategic Health Authority; both the University of Newcastle and Northumbria University and chaired by myself on behalf of HPA North East

Yours faithfully,

Shelley Lanser M.P.H., HonMFPH
Regional Environmental Epidemiologist

Appendix XI: Abstract, Oral Presentation at North East Regional Research and Development Conference, Strengthening the links between technology and healthcare, 8th March 2007

Public health decision-making: the value of geographical information systems (GIS) mapping

K.E. Joyce[1], Aarvold, J[1]., Lanser, S[2]. and Chandler, C[1].

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Introduction:

Technologies such as geographical information systems (GIS) have emerged during the past two decades as part of the Information Revolution and incorporate functions such as data storage, management, integration, analysis and presentation. GIS have wide and diverse applications in disciplines including engineering, business/marketing, urban planning and environmental management but remain underused in public health[1]. Here we report on the findings of a qualitative study examining the views and perceptions of the value of GIS mapping in public health decision-making. The idea of using GIS to promote interagency collaboration and data sharing is explored and unpicked.

Objectives:

- To examine how decision-makers value GIS technologies in public health.
- To understand the extent to which maps can be used as evidence in decision-making processes[2].

Method:

Twenty-three semi-structured interviews were conducted with decision-makers involved either directly or indirectly in public health practice. Interview recordings were transcribed verbatim and coded for thematic analysis.

Results:

Decision-makers tended to be positive about the use of GIS in public health and many volunteered potential opportunities to apply GIS mapping techniques further. Four discourses were highlighted through analyses, namely: data origins (Ontological Discourse), status (Power Discourse), application (Functionality Discourse) and reciprocity (Collaboration Discourse). The power of maps to integrate multiple, disparate datasets was viewed as important and respondents supported GIS mapping as a democratic means for communication.

Conclusion:

The study has demonstrated the value of GIS in informing decision-making. The findings can be translated to other fields, thereby sharing skills, knowledge and experience to promote collaboration and joined up thinking across the public health landscape.

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[1] Higgs,G., Gould, M. (2001). Is there a role for GIS in the 'new NHS'? *Health & Place*, **7**, 247–259.

[2] Sackett, D.L., Rosenburg, W.C. and Gray, J.A.M. (1996). Evidence based medicine: what it is and what it isn't. *British Medical Journal*, **312**, 71-72.